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Industry Perspectives On Reusable Launch Vehicle Technicians

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INDUSTRY PERSPECTIVES ON REUSABLE LAUNCH VEHICLE TECHNICIANS

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of

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To Savannah. You are the reason I did this.

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ABSTRACT

Vlasman, Brent A. M.S., Purdue University, May, 2010. Industry Perspectives on Reusable Launch Vehicle Technicians. Major Professor: David Stanley.

Companies in the commercial space industry are developing a new generation of reusable launch vehicles (RLV). The Federal Aviation Administration's Office of Commercial Space Transportation (FAA/AST) is working on creating a new generation of technicians, the RLV Aerospace Maintenance Technician (RAMT), who is capable of maintaining these new vehicles. However, the FAA/AST does not yet know the knowledge required of this technician in order to maintain this new vehicle type. This exploratory, qualitative study examined the subject area knowledge required of reusable launch vehicle technicians in the United States' sub-orbital commercial space industry. The study sought to answer the question, "What are important subject areas for the training of RLV technicians?" This was accomplished by interviewing subject matter experts from the companies developing sub-orbital RLVs over the telephone. The interviews were recorded, transcribed, and then analyzed for common themes using Strauss and Corbin's Grounded Theory, qualitative content analysis, and cross case analysis. This study found that important subject areas for the training of RLV technicians include: Rocket Propulsion, Aviation Maintenance, Electronics/Electrical Systems, Mechanical Systems, Engineering, Project Management, and Aerodynamics. Recommendations are made to develop an RLV curriculum based on these subject areas as a supplemental area of study for aviation maintenance training programs.

CHAPTER 1. INTRODUCTION

This chapter outlines the research area and discusses the intentions of the study. This chapter provides background information on the subject being studied, and defines the focus area of the project and its significance. Important assumptions and limitations are presented and specific technical terms are defined.

1.1. Objectives

The goal of this research was to contribute to the body of knowledge regarding the reusable launch vehicle (RLV) maintenance technician. The research question this project sought to answer was: "What are important subject areas for the training of RLV technicians?"

1.2. Background

After *SpaceShipOne* claimed the Ansari X-prize in 2004, numerous companies have emerged seeking to profit from the fledgling commercial space industry. These companies, many financed by ultra-wealthy entrepreneurs, are in various stages of developing reusable spaceships with the intention of taking fare-paying customers for a ride beyond the earth's atmosphere and back. These companies each plan on developing and operating their own newly designed aerospace vehicle.

1.3. Scope

This study examined maintenance and operations in the privatized commercial space industry. At the time of the study, the industry consisted of a small number of young companies that designed and developed space hardware. This study focused on commercial space companies that intended to operate a space tourism business. The space tourism concept being developed consisted of an adventure-type thrill ride in an RLV. The companies examined in this study plan on eventually operating multiple RLVs that will generate revenue through ticket sales.

This study focused on RLV maintenance and operations. Within RLV maintenance and operations, the focus of this study was on the maintenance of sub-orbital RLVs. Although both orbital and sub-orbital RLVs were being designed and developed and both will require maintenance, it was assumed that sub-orbital vehicles would be operational first and thus deserved more urgent attention. The study addressed a gap in knowledge related to the training and potential certification of the personnel that perform maintenance on an RLV.

To determine the characteristics of an RLV technician, nine companies were selected based on their intentions of operating a sub-orbital RLV. These companies represented the majority of known existing sub-orbital commercial space companies. Four of the companies participated in telephone interviews that yielded information on the important subject areas that an RLV technician would need to perform maintenance on their specific RLV. The data was then analyzed for commonalities between the company-defined characteristics.

1.4. Significance

Commercial space is a growing industry. In its *2008 Year in Review* the Federal Aviation Administration's Office of Commercial Space Transportation (FAA/AST) reported that commercial launch revenues "grew almost 100 percent between 2004 and 2008, from roughly US$1 billion to nearly US$2 billion" (FAA/AST, 2008, p.18). This significant growth potential has attracted some serious interest. Most of the emerging space tourism companies are supported by successful entrepreneurs such as: Richard Branson of *Virgin Records* with his start-up *Virgin Galactic*, Jeff Bezos of *Amazon.com* with his start-up *Blue Origin*, John Carmack, co-creator of the *Doom* and *Quake* videogames, with *Armadillo Aerospace*, Elon Musk, cofounder of *PayPal*, with *SpaceX*, and Robert Bigelow, founder of *Budget Suites America*, with *Bigelow Aerospace*. Given the depth of readily available financial backing, commercial space is poised to grow tremendously – accelerating the need for technical support infrastructure for RLVs.

One significant problem within the commercial space industry is a lack of experience in operating and maintaining aerospace vehicles. The only existing launch vehicle with a known maintenance history is the recently decommissioned Space Shuttle Orbiter. The Space Shuttle Orbiter is not a commercially viable RLV because its turnaround times averaged in months; as opposed to the days, hours, or even minutes expected of the new generation RLVs designed for space tourism.

In addition to the lack of maintenance experience, commercial space companies do not have the large budget that NASA used to maintain the Shuttle. Cost of operation has driven many aspects of the commercial space industry, from the vehicle concept designs to the facilities from which they operate. Maintenance costs play a pivotal role in the future of commercial space; however, it remains to be determined exactly who will perform the maintenance on these vehicles.

The purpose of this project is to help define subject areas for preparing RLV technicians who will perform the maintenance of these emerging RLV designs. Unlike the automotive and aircraft industries, the RLV industry lacks a nationally recognized, standardized system for training technicians. The goal of this project is to contribute to the understanding of RLV maintenance by contributing to the description of an RLV technician.

1.5. Definitions

Expendable launch vehicle means a launch vehicle whose propulsive stages are flown only once, (Code of Federal Regulations Title 14, Part 401).

Experimental permit or *permit* means an authorization by the FAA to a person to launch or reenter a reusable suborbital rocket, (Code of Federal Regulations Title 14, Part 401).

Human space flight incident means an unplanned event that poses a high risk of causing a serious or fatal injury to a space flight participant or crew, (Code of Federal Regulations Title 14, Part 401).

Instantaneous impact point means an impact point, following thrust termination of a launch vehicle, calculated in the absence of atmospheric drag effects, (Code of Federal Regulations Title 14, Part 401).

Launch vehicle means a vehicle built to operate in, or place a payload in, outer space or a suborbital rocket, (Code of Federal Regulations Title 14, Part 401).

Reusable launch vehicle (RLV) means a launch vehicle that is designed to return to Earth substantially intact and therefore may be launched more than one time or that contains vehicle stages that may be recovered by a launch operator for future use in the operation of a substantially similar launch vehicle, (Code of Federal Regulations Title 14, Part 401).

Safety critical means essential to safe performance or operation. A safety critical system, subsystem, component, condition, event, operation, process, or item is one whose proper recognition, control, performance, or tolerance is essential to ensuring public safety. Something that is safety critical item creates a safety hazard or provides protection from a safety hazard, (Code of Federal Regulations Title 14, Part 401).

Space flight participant means an individual, who is not crew, carried aboard a launch vehicle or reentry vehicle, (Code of Federal Regulations Title 14, Part 401).

Suborbital rocket means a vehicle, rocket-propelled in whole or in part, intended for flight on a suborbital trajectory, and the thrust of which is greater than its lift for the majority of the rocket-powered portion of its ascent, (Code of Federal Regulations Title 14, Part 401).

Suborbital trajectory means the intentional flight path of a launch vehicle, reentry vehicle, or any portion thereof, whose vacuum instantaneous impact point does not leave the surface of the Earth, (Code of Federal Regulations Title 14, Part 401).

Vehicle safety operations personnel means those persons whose job performance is critical to public health and safety or the safety of property during RLV or reentry operations, (Code of Federal Regulations Title 14, Part 401).

1.6. Assumptions

The assumptions for this study included:

- Cooperation of the existing population of commercial space companies.
- Participant comprehension of interview questions.
- Logistical capability to conduct interviews, including access to any necessary recording equipment and data coding software or statistical analysis software.

- No initial research or travel funding.
- All participants communicated in English.
- The companies involved have a concept of an RLV technician.
- Telephone interviews were adequate to collect all pertinent data (budgetary restriction).
- Results were communicated to the participating organizations and abbreviated versions of this study were published in appropriate journals.

1.7. Delimitations

The delimitations for this study included:

- Focused only on sub-orbital RLVs.
- Focused only on commercial (not government funded) entities.
- Only contacted companies with operations in the United States.
- The population was defined by the companies listed by the FAA/AST 2008 annual report.
- Time only allowed for one interview of the identified companies. This interview was the source of data for the project.
- Studied only the characteristics of a proposed RLV technician, not the maintenance and operations plan, system, or infrastructure.
- Financial information and analysis concerning RLV maintenance was not included in this study.
- Financial success of the commercial space industry was not included in this study.
- This project did not intend to produce a curriculum for an RLV technician.
- This project did not intend to produce a certification for an RLV technician.
- The FAA/AST policies and definitions were used as the ultimate authority for continuity.
- The only data used in this project, other than published literature, were interview transcripts from representatives of commercial RLV operators.

1.8. Limitations

The limitations for this study included:

- This is an exploratory study.
- The qualitative data gathered might vary largely between and amongst the companies contacted.
- Each company's RLV might be so unique that generalizations from this study are impractical.
- Commonalities among responses might not exist.
- Results might be of little value to the aviation industry because of the potentially miniscule connection between RLV maintenance and existing aviation maintenance.

1.9. Summary

This chapter introduced the study of RLV maintenance technicians. This chapter discussed the scope of the project as well as its significance. In this chapter industry specific terms were identified and defined, and assumptions, limitations, and delimitations for the project were discussed.

CHAPTER 2. REVIEW OF LITERATURE

This chapter provides an overview of the commercial space industry, discusses reusable launch vehicle (RLV) maintenance, and defines industry-specific terms. This chapter will familiarize the reader with U.S. government policy relating to space exploration in general, as well as proposed RLV maintenance concepts. This section provides a profile of the companies in the commercial space industry.

2.1. Commercial Space Industry

Space tourism has technically existed since 2001 when Dennis Tito paid $20m (£14m) for a ride to the International Space Station (BBC, 2001). Tito's flight revived public interest in space travel and space exploration. Renewed interest in space, combined with the fruition of emerging technologies, caught the attention of billionaire entrepreneurs who are attempting to bring space to the masses. However, the extremely high cost of space tourism, as demonstrated above, currently restricts the market to a very small size.

In an effort to address the issue of cost in space transportation, the X-Prize Foundation developed a competition to create a new space-race. "The Ansari X PRIZE, won by Burt Rutan and *Scaled Composites* in 2004, was a $10 million competition to build a privately funded craft that reaches a sub-orbit of 100 km twice in two weeks" (X-prize Foundation, 2009). The features that made this challenge unique were private funding and a reusable vehicle. This competition brought media attention to space tourism and contributed to the development of the RLV concept.

In a speech delivered at the annual TED convention, Ansari X-prize winner Burt Rutan elaborated on the future of the space tourism industry. His predictions of the space tourism industry were that “It will be very high volume. We think 100,000 people will fly by 2020” (Rutan, 2007). In 2004, Rutan proved that a private company can develop a reusable launch vehicle, from the ground up, and fly humans into space. The next step involves scaling up operations in order to reach the tipping point where costs are reduced enough to increase the potential market. A fundamental component of this next step will be maintenance of the vehicle.

Commercial space tourism is an emerging entrepreneurial industry. There are many small start-up companies competing for the commercial space market. Technology has advanced to the point where a private company now has the capacity to put humans into space. These companies tend to focus on space vehicles that have either orbital or sub-orbital trajectories. The business model for most space tourism companies will be providing a thrill-type ride for paying customers who will get the experience of either a sub-orbital or orbital flight out of the earth’s atmosphere.

To identify the current state of the commercial space tourism industry and the space vehicles being designed and developed, the author performed a comprehensive review of available literature. The review of literature focused on existing journal articles, government documentation and policies including the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and the federal government, as well as industry publications and conference proceedings.

2.2. Launch Vehicle Types

Operational costs must be significantly lower than comparable government funded programs for a privately funded commercial space company to be successful. In order to achieve this low level of operating costs, a new generation of space vehicles must be developed. There are essentially three types of launch vehicles: expendable, hybrid, and reusable. Each vehicle type has advantages and disadvantages depending on the level of expected use of the vehicle.

An expendable launch system is a launch vehicle in which no part of the vehicle is reused on another flight. Gstattenbauer, Franke, and Livingston point out that “All current launch platforms (other than the Space Shuttle) are expendable launch vehicles (ELVs)” (2006, p.1). The ELV system has the advantage of being less expensive and simpler to initially develop. However, ELVs “will have trouble responding to higher launch rates” (Gstattenbauer, Franke, & Livingston, 2006, p.10).

Hybrid launch vehicles (HLV) represent the middle ground between ELVs and RLVs. Gstattenbauer et al. (2006) define HLVs as a vehicle that has “a first-stage reusable, second-stage expendable, launch system” (p. 2). These vehicles are slightly more expensive to develop than ELVs, but offer a more robust airframe and flexible flight envelope. HLVs offer some benefit in life cycle costs over ELVs for “current or modest increases in predicted launch rates” (Gstattenbauer et al., 2006, p.10).

A Reusable Launch Vehicle (RLV) is generally defined as “any vehicle which can take-off, exit the earth’s atmosphere and land multiple times” (Jackson & Smith, 2000, p.1). Most commercial space companies have focused their efforts on the development and operation of RLVs. Although the initial development costs of RLVs are the highest, “the extremely low direct operating costs quickly outweigh the high development costs for launch rates above about 20 per year” (Gstattenbauer et al., 2006, p. 10). Most commercial space companies prefer the RLV design philosophy because of the long term cost savings the RLV offers. In Gstattenbauer et al.’s study, the maintenance costs for the (orbital) RLV system “equated to $80 million dollars after 400 launches for the reusable launch vehicle. That is pennies compared to the total cost of the system” (2006, p. 6).

2.3. RLV Maintenance

Any reusable vehicle, such as aircraft and automobiles, requires maintenance. The current RLVs are at the beginning of their life cycle, with many RLV concepts still on the drawing board. In accordance with previous discussions for reducing total cost, designers of RLVs should emphasize life cycle cost reduction as a primary focus in their design philosophies. Bowcutt, Gonda, Hollowell, and Ralston (2002) developed a model to identify cost drivers affecting RLV life cycle costs. The results of their model indicate “turnaround time is the biggest driver of life cycle cost, indicating that the technology set and design architecture that maximize vehicle utility may be optimum” (p. 13). Some RLVs are in the prototype stage, some are in the proof of concept stage, and others are operational at the present time. As the number of operational RLVs increases, it would be assumed the demand for qualified maintenance personnel will also increase.

Maintenance of an RLV is still somewhat unknown. Scholars have created projections of various RLV maintenance concepts in attempt to describe what the maintenance itself will look like. These concepts range from aircraft-like maintenance models to Space Shuttle-like maintenance models. Morris, White, Davis, and Ebeling (1995) illustrated the concept of RLV maintenance using the parameters of “the ratio of scheduled to unscheduled maintenance, the crew size required to do the hands-on labor, and the power-on time required for ground servicing” (p. 3). Morris et al. also explained the differences between a typical aircraft maintenance crew and a typical Space Shuttle maintenance crew. The maintenance crew required to perform maintenance on an aircraft “normally involves a crew chief and one or two technicians with specialized skills required for the task” (Morris et al., 1995, p. 3). The maintenance crews required to perform maintenance on the Space Shuttle “frequently are made up of a test conductor, a systems, quality, and safety engineer, and a technician” (Morris et al., 1995, p.3). Morris et al. used the model they created for the Space Shuttle maintenance concept to project the supportability requirements for an RLV. Their model “resulted in a manpower requirement of 940 hands on support personnel for performing productive work for a fleet size of 7 vehicles to achieve 30 flights per year” (Morris et al, 1995, p. 7). *Virgin Galactic*, one of the emerging commercial space tourism companies, plans to operate five vehicles, each flying more than 30 flights per year. Thus, the supportability of RLVs is a significant issue that needs to be addressed for the commercial space tourism industry to prosper.

2.4. Government Perspective of Commercial Space

The *U.S. National Space Policy* (2006) discussed the United States' involvement and future plans for space exploration and development. The policy supported the commercial space industry and stated that the United States was “committed to encouraging and facilitating a growing and entrepreneurial U.S. commercial space sector” (p. 2). The policy described many goals for current and future space programs. The policy's goal for the commercial space sector was to “enable a dynamic, globally competitive domestic commercial space sector in order to promote innovation, strengthen U.S. leadership, and protect national, homeland, and economic security” (p. 2). Although supportive of the commercial space effort, the policy did cite the need for a technical workforce that might not currently exist. The policy called for a supporting workforce by specifying the need to “develop space professionals” (p. 3). Included in the development of these space professionals was a need to “establish standards and implement activities to develop and maintain highly skilled, experienced, and motivated space professionals within their workforce” (p. 3).

The federal space policy established that the leadership of the United States was supportive of the commercial space industry, but lacked specific information regarding regulations related to commercial space maintenance and operations. The author then examined the FAA for potential commercial space regulations where it was discovered that a division of the FAA was responsible for regulating the commercial space industry. The wealth of information gathered from the FAA was accessed through the FAA website (Federal Aviation Administration Office of Commercial Space Transportation (FAA/AST) 2005a, 2005b, 2008a, 2008b, 2009). This paragraph was found as the introduction to many articles published about the commercial space industry:

> **About the Office of Commercial Space Transportation**
> The Federal Aviation Administration's Office of Commercial Space Transportation (FAA/AST) licenses and regulates U.S. commercial space launch and reentry activity, as well as the operation of non-federal launch and reentry sites, as authorized by Executive Order 12465 and Title 49 United States Code, Subtitle IX, Chapter 701 (formerly the Commercial Space Launch Act). FAA/AST's mission is to ensure public health and safety and the safety of property while protecting the national security and foreign policy interests of the United States during commercial launch and reentry operations. In addition, FAA/AST is directed to encourage, facilitate, and promote commercial space launches and reentries. Additional information concerning commercial space transportation can be found on FAA/AST's web site at http://ast.faa.gov.

The above description clearly stated that the FAA's Office of Commercial Space Transportation regulates the space tourism industry. The author followed the direction of the above paragraph and reviewed the information available from the FAA/AST web site.

The FAA/AST web site had multiple sections with a broad range of information in each section. Of particular interest to the author were archived publications created by the Office of Commercial Space Transportation including various annual space tourism industry reviews, documents which projected future states of the industry and what they might look like, and guidelines for developing the framework of the commercial space industry. The author focused on information regarding supportability of RLVs and the sustainability of the commercial space industry. The FAA/AST clarified the support functions of RLVs in a document titled *Guide to Commercial Reusable Launch Vehicle Operations and Maintenance* (FAA, 2005b).

The purpose of the FAA's maintenance and operations guide was to "provide industry with insight into what the DOT/FAA views as important considerations for operations and maintenance of RLVs" (FAA, 2005b, p. 1). The document also addressed "what the FAA/AST may expect to review and evaluate in an application for a license or permit concerning RLV operations and maintenance" (FAA, 2005b, p.1). The guide specified that the maintenance and operations it discussed were not limited to either orbital or sub-orbital RLVs. The guide was only meant as a preliminary document in that, "many years of RLV flight experience are required before and appropriate set of regulations for RLV operations and maintenance can be developed" (FAA, 2005b, p. 2).

2.5. <u>Operations and Maintenance Guide 1.0</u>

The FAA's *Guide to Commercial Reusable Launch Vehicle Operations and Maintenance* defined its concept of an RLV technician in a section that addressed RLV Support Personnel. The RLV technician was referred to as an "RLV Aerospace Maintenance Technician (RAMT)" (FAA, 2005b, p. 6). The RAMT was defined in section 7.2:

> 7.2. RLV Aerospace Maintenance Technician (RAMT). The RAMT should be familiar with and demonstrate practical and hands-on knowledge of system and subsystem functions and operational tests that relate to the operations and maintenance of particular vehicles. The RAMT should demonstrate proficiency in each system or subsystem of the vehicle if that system or subsystem is used in the vehicle or support equipment. Each system and subsystem RAMT should be identified by name and should have the following skills and qualifications for his/her system or subsystem:
> <u>Subject Knowledge</u>
> Understand the function and operation of the applicable system or subsystem.
> <u>Task Knowledge</u>
> Know how to predict, isolate, and resolve problems.
> Know step-by-step procedures of the technician documents.
> Know why and when the task must be done.

Task Performance
Perform and complete maintenance tasks.

This definition suggested that the RAMT might have specific training for the RLV or specific vehicle system or subsystem he or she would be working on. Although the definition omitted the specific training program required to adequately prepare a RAMT to perform maintenance on an RLV, the guide did provide recommendations for training, “The RLV operator may use one or any combination of the following programs and models for RAMT approval during its rating assessment process:

- FAA Airframe, Powerplant Mechanic, or both, certification programs.
- SpaceTEC Aerospace Technician Certification program.
- Automotive Service Excellence Certification model.” (FAA, 2005b, p. 6).

The FAA provided justification for using these certification programs as potential models, “Rationale: RLV Aerospace Maintenance Technicians ensure compliance with safety- critical operations and safety-critical maintenance activities in support of safe RLV operations” (FAA, 2005b, p. 6).

The FAA’s recommendation proposed that any of these three certification programs, or combinations of the three, could serve as the foundation for creating a model for the RAMT rating. This implied that the RAMT training might be specific to each company’s RLV, system, or subsystem. In light of this, the author gathered information about sub-orbital commercial space companies and their proposed RLVs. Each of the companies discussed will be contacted by the author in an effort to develop a list of subject knowledge areas required of their future RAMTs.

2.6. Suborbital Industry Snapshot

As discussed previously, the scope of this study was limited to companies that intend to maintain a sub-orbital vehicle. This limitation was based on the levels of space tourism developed by John Spencer (2004) of the Space Tourism Society. Spencer identified the “levels of space tourism experiences” in order from largest number of participants and lowest cost (bottom), to smallest number of participants and highest cost (top) as shown in Figure 1.

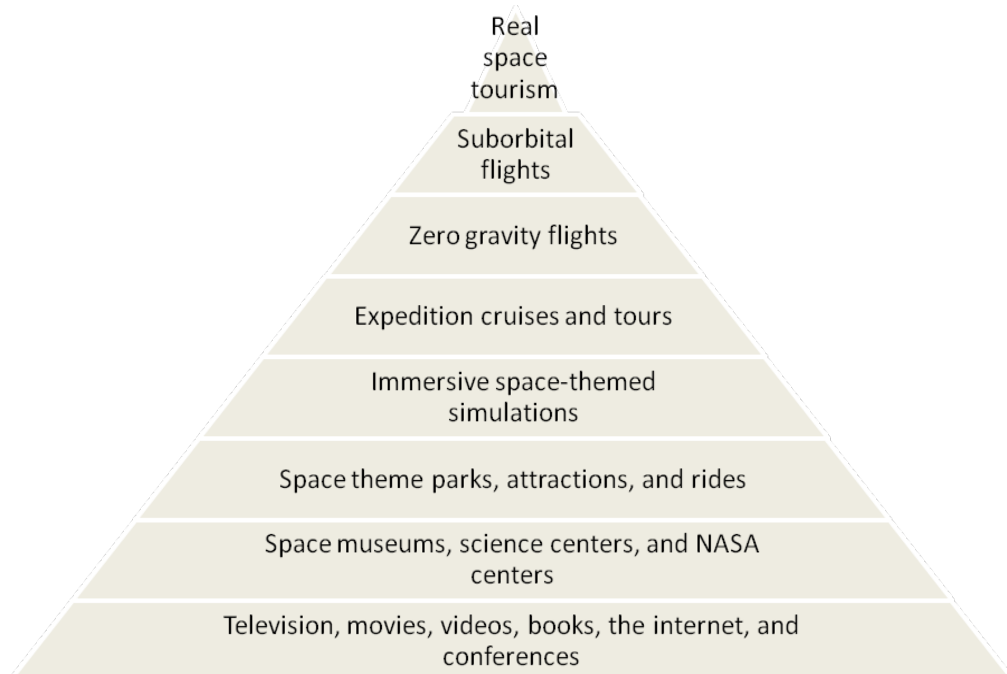

Figure 1. Levels of space tourism experience.

Figure 1 defined the main segments of the future space tourism market (Spencer, 2004, p. 55). Within these segments, sub-orbital flights was chosen to be studied.

The following is a brief discussion of each commercial space tourism company that is planning, developing, or operating a sub-orbital RLV as documented in the *2008 U.S. Commercial Space Transportation Developments and Concepts: Vehicles, Technologies, and Spaceports document published* in January 2008 by the FAA:

- Armadillo Aerospace: “Armadillo Aerospace, a former competitor for the Ansari X Prize, is developing a family of vehicles designed for suborbital and, eventually, orbital flight operations” (p. 21).
- Benson Space Company – BSC Spaceship: “Benson Space Company (BSC), of Poway, California, was established by former SpaceDev CEO Jim Benson in September 2006 to develop and operate vehicles to serve the suborbital space tourism market” (p. 22).
- Blue Origin – New Shepard: “Blue Origin is developing the New Shepard Reusable Launch System, a suborbital, vertical-takeoff, vertical-landing RLV for commercial passenger spaceflights” (pp. 22-23).
- Masten Space Systems – XA 1.0: “Masten Space Systems of Mojave, California, is developing the eXtreme Altitude (XA) series of suborbital RLVs, initially designed to carry small research payloads” (p. 24).
- Rocketplane Global – Rocketplane XP: “Rocketplane Global, a subsidiary of Rocketplane Inc. of Oklahoma City, Oklahoma, is developing the Rocketplane XP suborbital RLV” (pp. 25-26).
- Scaled Composites, LLC/The Spaceship Company/Virgin Galactic – SpaceShipTwo: “Scaled Composites, LLC, and Virgin Galactic, LLC a subsidiary of the Virgin Group of Companies, announced the formation of a joint venture, called The Spaceship Company (TSC), LLC, in July 2005. The purpose of TSC is to oversee development and production of SpaceShipTwo, a commercial suborbital spacecraft based on technology developed for SpaceShipOne. TSC will produce the first five SpaceShipTwo vehicles for Virgin Galactic, which plans to put them into commercial service once test flights are completed, offering suborbital space flights for private individuals, science research, and payload” (p. 27).
- SpaceDev – Dream Chaser: “Dream Chaser is an RLV under development by SpaceDev to serve suborbital and orbital applications” (pp. 27-28).

- Space Access, LLC – Skyhopper: “In December 2007, Space Access, LLC, of Huntertown, Indiana, announced its plans to develop a suborbital RLV called Skyhopper. The vehicle would take off and land on a conventional runway, and use ejector ramjet engines with liquid hydrogen fuel, as opposed to conventional rocket engines” (p. 28).
- TGV Rockets, Inc. – Michelle-B: “TGV Rockets, Inc. (TGV) is developing Michelle-B, a fully reusable, remotely-piloted suborbital vehicle, designed to carry up to 1,000 kilograms (2,200 pounds) to an altitude of 100 kilometers (62 miles)” (pp. 29-30).
- XCOR Aerospace – Xerus: “In July 2002, XCOR Aerospace announced plans to develop a suborbital RLV, named Xerus. The Xerus would take off horizontally from a runway under rocket power and fly to an altitude of 100 kilometers (62 miles) before returning for a runway landing. XCOR plans to use Xerus for a variety of suborbital missions, including microgravity research, suborbital tourism, and even the launch of very small satellites into orbit” (p. 31).

The author recognizes that the above mentioned companies comprise a relatively small sample size. The author intends to develop and administer an interview to the above companies that asks each to define the important subject knowledge areas of a RAMT for their specific RLV. The author believes that enough information can be gathered, assuming adequate cooperation, from these sources to generate significant analysis and conclusions.

The purpose of this project is to help define the technician that will maintain these emerging RLV designs. Unlike the automotive and aircraft industries, the RLV industry lacks decades of maintenance experience and a nationally recognized, standardized system for training technicians. The goal of this research is to contribute to the definition of a sub-orbital RLV technician by determining what subject areas are important for their training.

2.7. Summary

This chapter presented information gathered from other publications regarding RLV maintenance. This chapter discussed the state of government policy as well as provided a profile of the active commercial space companies. The operations and maintenance guidelines examined in this chapter served as the foundation for the study.

CHAPTER 3. METHODOLOGY

This chapter explains the approach and overall plan of the proposed study. The research framework is established and the data collection process is defined. The data collection instrument is discussed and a time schedule for the project is presented.

3.1. Study Purpose

The commercial space industry is a young, rapidly growing industry fueled by entrepreneurial behemoths with billion dollar bank accounts. These entrepreneurs founded companies planning to profit from the emerging sub-orbital commercial space tourism industry. However, these companies must develop their own launch vehicles, as none currently exist that can operate at a low enough cost level. While the current focus of the industry is on vehicle design, vehicle maintenance and operations should be studied with equal vigor. The purpose of this project is to help describe the expertise of the technicians maintaining these emerging RLV designs.

3.2. Exploratory, Qualitative Research

This is an exploratory study. “An exploratory study is undertaken when not much is known about the situation at hand, or no information is available on how similar problems or research issues have been solved in the past” (Sekaran, 2003, p. 119). This study intends to generate new information that could be refined by further examination with additional research, “exploratory studies are important for obtaining a good grasp of the phenomena of interest and advancing knowledge through subsequent theory building and hypothesis testing" (Sekaran, 2003, p.119). The exploratory nature of this study seeks to shed some initial light on the training needs of RLV technicians.

The exploratory nature of this study, lack of knowledge related to the topic, and the descriptive aspect of the research question are most appropriately addressed using a qualitative research methodology. Qualitative methods are a particularly appropriate starting point for "new fields of study where little work has been done, few definitive hypotheses exist and little is known about the nature of the phenomenon" (Patton, 2002, p.193). Lack of existing information and knowledge contributed to the selection of a qualitative approach because "qualitative research techniques are typically applied in situations where little is known about a particular domain" (Wiggins, 1999, p. 164). This study is one of the first to address the knowledge requirements of an RLV technician. The intent of the study is to create a starting point that subsequent research could further develop.

3.3. Theoretical Framework

"The theoretical framework is the foundation on which the entire research project is based" (Sekaran, 2003, p. 97). The theoretical foundation of this study is Grounded Theory. At its roots, Grounded Theory empowers researchers to explore subjects without preconceived hypotheses. Instead, the researcher is allowed to collect data on a phenomenon of interest then examine the data for emergent hypotheses. According to Patton (2002, p. 125) the fundamental question of Grounded Theory is: "What theory emerges from systematic comparative analysis and is grounded in fieldwork so as to explain what has been and is observed?" This theoretical framework allows the researcher to make assertions about what knowledge an RLV technician ought to posses, to create theory, based on the data collected during this study.

The intent of Grounded Theory is to create or build theory rather than test theory (Strauss & Corbin, 1998). According to Patton (2002),

> Grounded theory focuses on the process of generating theory rather than a particular theoretical content. It emphasizes steps and procedures for connecting induction and deduction through the constant comparative method, comparing research sites, doing theoretical sampling, and testing emergent concepts with additional fieldwork (p. 125).

Grounded Theory allows the researcher to openly analyze the data collected and make assertions based solely on his interpretation of this data. This theoretical framework appropriately addressed the research question, and ultimately enabled the researcher to contribute to the description of an RLV technician.

Grounded Theory is particularly appropriate for this study because it allows the researcher to enter the field and collect data without preconceived categories for participant responses. This seemingly minute detail had large implications for the results of the study. Grounded Theory allows the researcher to use truly open-ended interview questions, which in turn permitted the respondent "to describe what is meaningful and salient without being *pigeon holed* into standardized categories" (Patton, 2002, p. 56). Much data might have been omitted or improperly categorized if the researcher forced participants to think about their responses in terms of such arbitrarily created categories.

Although this study is framed using Grounded Theory, the researcher is conscious of and interested in applying what Patton (2002) calls Truth and Reality-Oriented Correspondence Theory to the study. According to Patton (2002, p. 91), one of the foundational questions of Truth and Reality-Oriented Correspondence Theory is: "What's really going on in the real world?" This theoretical framework is also appropriate for the research question, and is considered throughout the study because of its focus on objectivity. The Technology community in the academic world prefers objective research, and this theory guided the qualitative researcher to conduct a study as objectively as possible. Patton (2002, p. 93) summarized the theory by stating:

> In short, you incorporate the language and principles of 21st-century science into naturalistic inquiry and qualitative analysis to convey a sense that you are dedicated to getting as close as possible to what is really

> going on in whatever setting you are studying. Realizing that absolute objectivity of the pure positivist variety is impossible to attain, you are prepared to admit and deal with imperfections in a phenomenologically messy and methodologically imperfect world, but you still believe that objectivity is worth striving for.

The researcher plans to keep the concepts and techniques of Truth and Reality-Oriented Correspondence, the longing for objectivity, conscious throughout the study.

3.4. <u>Sampling</u>

"There are no rules for sample size in qualitative inquiry" (Patton, 2002, p.244).

The qualitative sampling strategies used for this study are very different than those of quantitative research. The small sample size of this study might make a quantitative researcher uncomfortable, however "qualitative inquiry typically focuses in depth on relatively small samples, even single cases (N = 1), selected *purposefully*" (Patton, 2002, p. 230). This study uses a sample selected purposefully. Another significant characteristic of qualitative sampling is that the "validity, meaningfulness, and insights generated from qualitative inquiry have more to do with the information richness of the cases selected and the observational/analytical capabilities of the researcher than with sample size" (Patton, 2002, p. 245).

The following is a short discussion of purposeful sampling and how it applies to this study. Sekaran (2002) defines purposive sampling as "confined to specific types of people who can provide the desired information, either because they are the only ones who have it, or conform to some criteria set by the researcher" (p. 277). In the commercial space industry, the space tourism companies are responsible for the maintenance of their RLV. This suggests that the companies are the subject matter experts regarding maintaining their particular RLV. Thus, the commercial space companies possess the information necessary to answer the research question. The sample for this study is the companies developing sub-orbital RLVs.

There are multiple purposive sampling methods. The sample for this study is selected using three techniques of purposive sampling: criterion based, critical case, and maximum variation sampling. The sample is originally created with emphasis on criterion sampling, then consideration is given to critical case and maximum variation sampling techniques. Criterion based sampling seeks "to review and study all cases that meet some predetermined criterion of importance" (Patton, 2002, p. 238). The criteria used for this study are created by the researcher and included the following: commercial space company with operations in the U.S., not government funded, plan to operate a sub-orbital RLV, recognized by the FAA/AST in their annual reports. The companies that met these criteria are identified in the review of literature section, and included the following companies:

- *Armadillo Aerospace*
- *Benson Space Company*
- *Blue Origin*
- *Masten Space Systems*
- *Rocketplane Global*
- *Scaled Composites, LLC/The Spaceship Company/Virgin Galactic*
- *SpaceDev*
- *Space Access, LLC*
- *TGV Rockets, Inc.*
- *XCOR Aerospace.*

These are the companies that meet the criteria determined appropriate for the study using criterion based, purposive sampling.

The sample is determined primarily using criterion based sampling, but critical case and maximum variation sampling are also considered. The following is a discussion of each and their relevance to the study.

Critical case sampling devotes special attention to critical cases. Critical cases “are those that can make a point quite dramatically or are, for some reason, particularly important in the scheme of things” (Patton, 2002, p. 326). For this study, *Scaled Composites, LLC/The Spaceship Company/Virgin Galactic* is determined by the researcher to be a critical case. This is the company that won the Ansari X-prize in 2004, arguably had the best financial support, and the most advanced flight hardware of the companies in the sample. The researcher felt that this company is the industry leader at the time of the study, and thus had the most experience and knowledge related to RLV technicians and maintaining an RLV. This company also had the most ambitious timeline for initial revenue flights, and most ticket deposits. *Scaled Composites, LLC/The Spaceship Company/Virgin Galactic* is determined to be a critical case based on these characteristics.

Maximum variation sampling is also considered for this study. The title of this sampling technique is rather telling of its emphasis - creating as diverse a sample as possible. The value in maximum variation sampling is that “any common patterns that emerge from great variation are of particular interest and value in capturing the core experience and central, shared dimensions of a setting or phenomenon” (Patton, 2002, p.235). The variation for this study focused on launch system architecture. In the sub-orbital commercial space industry, there is no “right” way to get to space and back. The rich mix of launch architectures range from horizontal takeoff and landing to launching from a high-altitude balloon and parachuting back to earth. The researcher seeks to include as many different launch system architectures in the sample as possible based on the criteria used, and the willingness of the participants. This sampling technique added to the study by examining if diversity of launching philosophy translates to unique technician subject area training needs.

3.5. Data Collection

Data will be collected through telephone interviews for this study. Telephone interviewing is used because direct observation is not possible due to time and funding constraints, a common obstacle according to Wiggins (1999), "where time is a limiting factor, both researchers and operators alike may be forced into situations that may not necessarily be optimal" (p. 95). Although perhaps not ideal, interviewing could offer some advantages to the researcher. According to Patton (2002), interviewing allows the researcher to "enter into the other person's perspective" (p. 341). This enables the researcher to inquire about what subject areas are important to each RLV company.

The researcher will call each RLV company, and ask to speak with a maintenance and operations expert at the company who can comment on behalf of the organization. The researcher will identify himself as a researcher from Purdue University who is conducting a study of RLV maintenance and operations. In doing this, the researcher assumed that each representative is knowledgeable regarding his/her company's RLV technician training concept, and also that the representative accurately reflects the organization. Patton (2002) asserts that this assumption is normal in qualitative inquiry, "Qualitative interviewing begins with the assumption that the perspective of others is meaningful, knowable, and able to be made explicit" (p. 341).

The interview questions in this study will be open-ended. According to Sekaran (2003) "open-ended questions allow respondents to answer them in any way they choose," whereas a closed question "would ask the respondents to make choices among a set of alternatives given by the researcher" (p. 329). Open-ended questions allowed the respondents the freedom to explain their expertise using the terminology they are comfortable with. Open-ended questions also provide the opportunity to capture "unexpected responses and this can be particularly useful when conducting an exploratory study" (Wiggins, 1999, p. 50). Open-ended questions are created to capture as much information as possible, and not impose limitations by using closed questions that would "force respondents to fit their knowledge, experiences, and feelings into the researcher's categories" (Patton, 2002, p. 348).

Consistent delivery of the interview is important for this study. To increase the continuity and consistency of responses, the researcher will create a standardized open-ended interview. According to Patton (2002, p. 346)

> There are four major reasons for using standardized open-ended interviews:
>
> 1. The exact instrument used in the evaluation is available for inspection by those who will use the findings of the study
> 2. Variation among interviewers can be minimized where a number of different interviewers must be used
> 3. The interview is highly focused so that interviewee time is used efficiently
> 4. Analysis is facilitated by making responses easy to find and compare.

Because this interview is used for a Master's thesis, it is necessary to have the instrument available for review by the graduate committee. It is also important for this project to maximize the amount of information received during a one-time, interview with participants. Cross-case analysis is also simplified because all respondents answered identically worded and sequenced questions.

The sequence of questions asked during the interview will be deliberate. According to Sekaran (2003) questions should be arranged such that "the respondent is led from questions of a general nature to those that are more specific, and from questions that are relatively easy to answer to those that are progressively more difficult" (p. 242). The researcher will accomplish this by asking general questions initially then gradually shifting to specific questions later in the interview. This technique is referred to as funneling (Sekaran, 2003).

In addition to deliberate sequencing and funneling technique, the researcher will compose the questions using a presupposition format. According to Patton (2002) the presupposition format asks a respondent "directly for description rather than asking for an affirmation of the existence of the phenomenon in question" (p. 369). This format reduces the likelihood of receiving binary responses by assuming that the participant will have an answer to the question. For example, a normal question might ask, “Do you require your technicians to receive additional training?” whereas a similar question using a presupposition format would ask, “What areas of additional training, if any, do you require your technicians to receive?” The difference is subtle, but the presupposition format results in more descriptive, information rich responses (Patton, 2002).

Additional considerations in the construction of the interview instrument include the opening statement, probing questions, and the final question. An opening statement will be created to explain the overall purpose of the interview to the participants (Patton, 2002). This statement will be sent via e-mail to the participants in preparation for the interview as well as discussed on the telephone prior to beginning the interview. Probing questions will be used where additional information is desired or clarification is needed after a response. A probing question is “a follow-up question used to go deeper into the interviewee’s responses” (Patton, 2002, p.372). Probing questions are not included as part of the interview protocol as they were not premeditated, rather they are used when appropriate at the discretion of the researcher. The final question of the interview will be created to give the participant an opportunity to provide feedback on anything they feel important in which they are not directly questioned about. According to Patton (2002) “in the spirit of emergent interviewing, open-ended interviewing, it’s important in formal interviews to provide an opportunity for the interviewee to have the final say” (p. 379). The final question will be used in case the participant entered the interview wanting to provide feedback but was never given an appropriate opportunity by the researcher.

The questions that will be asked in this study were created by the researcher under the advisement of technical experts. The researcher’s graduate committee, composed of three Purdue University Aviation Technology professors, helped refine and edit the questions used for this study. These professors have extensive experience in aviation maintenance and operations, curriculum development, and research methodologies. In addition to these professors, feedback was received from a subject matter expert from Purdue's Zucrow Rocket Propulsion Laboratory and a professor of qualitative research methods at Purdue University.

The data collection instrument and process for this study, including the interview questions, interview protocol, project brief document, telephone audio recorder, and transcription and data analysis methods, was validated by conducting a pilot study prior to collecting official data from the RLV companies. Participants in the pilot study included non-graduate committee professors of Aviation Technology at Purdue University as well as a subject matter expert from Purdue's Zucrow Rocket Propulsion Laboratory. All participants were asked for feedback following the trial study and no significant modifications were required before conducting the official study with RLV company participants. The pilot study validated the data collection instrument as well as the data analysis process for this study.

The study will use the following interview protocol:

Opening Statement:

Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes.

The purpose of this study is to identify important subject areas for the training of reusable launch vehicle (RLV) technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles.

Questions:

1. What do/did you look for in hiring your future/current technicians?
2. What additional knowledge areas would you like your technicians to possess?
3. What systems or subsystems should RLV technicians be familiar with?
4. If you started with a clean slate, in your opinion what are the most important subject areas an RLV technician must be familiar with?
5. With regards to RLV technicians, what have we not discussed that you feel is important?

The above interview will be administered over the telephone to maintenance representatives from the previously mentioned sample of commercial space companies. However, prior to conducting the actual interviews, the researcher will recruit the participants and develop rapport with each representative. In order to recruit participants, the researcher will “cold-call” the companies, and identify himself as a researcher from Purdue’s Aviation Technology Department, and ask for an RLV maintenance and operations contact person. Once in communication with the proper personnel, the researcher will develop rapport with the company representatives through multiple telephone conversations, e -mail message exchanges, and a “Project Brief” document.

Prior to the formal interview, all representatives will be sent an identical “Project Brief” document which introduces the researcher, discusses the project, and explains the interview procedure. The purpose of the project brief is to familiarize the participants with the research project as much as possible, while allowing them to review it at their own convenience. The project brief is included in Appendix C.

The telephone interviews will be recorded using a digital voice recorder. The importance of capturing the audio of an interview is paramount in qualitative inquiry, “The purpose of each interview is to record as fully and fairly as possible that particular interviewee’s perspective. Some method for recording the verbatim responses of people being interviewed is therefore essential” (Patton, 2002, p.

380). Patton emphasized the importance of recording in qualitative studies with the analogy, “As a good hammer is essential to fine carpentry, a good tape recorder is indispensable to fine fieldwork” (p. 380). Wiggins (1999) points out that “where video or audio recordings are made, participants must give explicit consent to the use of recording devices, and they retain the right to review recordings and withdraw the use of any information as necessary” (p. 74). Informed consent and confidentiality of participants will be documented in accordance with Purdue’s Institutional Review Board recommendations.

The next step of data collection is preparing transcripts of the interview audio files. All interview audio files will be transcribed by the researcher using a personal computer. The recorder used will be an Olympus VN-5200PC digital voice recorder connected to a telephone using an Olympus TP-7 Telephone Recording Adapter. The digital data will then be transferred to a personal computer. The software used for audio playback will be Windows Media Player and Microsoft Word 2007 will be used for transcription. The researcher will manually transcribe every interview in its entirety. All communication will be transcribed, including pauses, stutters, and audible stalls such as “um” and “uh” to preserve the integrity of the interview. This painstakingly accurate transcription is an important part of data collection as “The raw data of interviews are the actual quotations spoken by the interviewees” (Patton, 2002, p. 380). Directly following transcription, the audio files will be destroyed. Transcripts were then altered using a number-coding system to de-identify participants. Transcription of the interview data will mark the end of data collection and the beginning of data analysis.

3.6. Data Analysis

“Qualitative analysis transforms data into findings. No formula exists for that transformation” (Patton, 2002, p. 433).

“Because each qualitative study is unique, the analytical approach used will be unique” (Patton, 2002, p. 433).

Patton began his textbook on qualitative research methods with a brief discussion of the importance of the researcher in a qualitative study. While contrasting quantitative and qualitative research methods and techniques Patton summarized by stating, “In qualitative inquiry, the researcher is the instrument” (2002, p. 16). In light of this unique characteristic of qualitative research, at this point the researcher would like to deliberately highlight to the reader that purely objective analysis of qualitative data is nearly impossible. Throughout the data analysis process the researcher’s biases and experience likely will have an impact on the results of the study. The intent of the following sections is to explain as thoroughly as possible how the data will be analyzed with the intent of being transparent, thus hopefully adding credibility to the study.

As discussed previously, the theoretical foundation of this study is Grounded Theory. Grounded Theory allows the data to speak. To further explain what this means, an explanation of Grounded Theory in non-technical, original language is necessary. In a crude summary, quantitative studies traditionally seek to establish correlations or test predetermined hypotheses by gathering data from a sample, and analyzing them using statistical instruments backed by the Central Limit Theorem, with the intent of generalizing to a larger population. Unlike quantitative studies, in the qualitative world data analysis depends on the researcher, not on statistics. However, in qualitative inquiry the researcher is not allowed free reign over data analysis and interpretation. The researcher thus needs a set of tools, similar to those of statistics, to analyze his or her data. Grounded Theory can be thought as one of these tools.

On a high level, readers unfamiliar with Grounded Theory can think of it as *intuitive statistics*. In a qualitative study the data are often in the form of words. Raw data for this study will be interview transcripts. Although the data cannot be directly analyzed with statistics, the data can be read. Reading is a mental exercise, hence the concept of intuition. Grounded Theory frames the process by which a researcher can become so immersed in his or her data that analysis and interpretation become possible. This immersion process includes many steps.

The following paragraphs discuss the steps used to analyze the data for this study.

The first step following data collection and transcription is to read the transcripts multiple times to become familiar with the data. During the first pass through the transcripts no notes or markings will be made. During the second pass the researcher will make short notes in the margins of the transcript hardcopies. These notes will indicate information that appears important or to "jump off" the page for some reason. During this second read through the question is posed internally, "What is in this transcript? What information is here? How does this person relay information in his or her responses?" The third read through happens at a much slower rate than the first two. During this pass the researcher will begin to break the text into smaller pieces, line-by-line and word-by-word. The purpose of intentionally slowing down the pace of reading during this pass is to prevent drawing any conclusions too hastily. After the third pass, the researcher will begin the process of open coding.

Strauss and Corbin (1990, p. 61) defined coding as "The process of analyzing data." Codes are essentially labels for the data. These labels will be used later in the analysis to group data into categories based on similarity. Open coding is "the process of breaking down, examining, comparing, conceptualizing, and categorizing data" (Strauss & Corbin, 1990, p. 61). Open coding is used to start attaching labels to the data. The labels themselves are also words, but are typically more descriptive than the data they are associated with. According to Strauss and Corbin (1990, p. 67) the qualitative researcher has some freedom to name the labels (codes) what he or she chooses, "This is where most names come from – YOU! The name you choose is usually the one that seems most logically related to the data it represents, and should be graphic enough to remind you quickly of its referent." During the fourth pass code names will be created and inserted into the transcripts. The following format will be used to insert codes into the transcripts: **[code name here]**. For example: "Brent was tired **[fatigue]** from staying up all night working on his thesis." In this example the code “fatigue” was used to categorize Brent’s condition. To show exactly how the transcripts will be coded, both the original and the coded transcripts will be appended to this document.

To code the interview transcripts the researcher will use line-by-line analysis. Line-by-line analysis “involves close examination, phrase by phrase, and even sometimes of single words. This is perhaps the most detailed type of analysis, but the most generative” (Strauss & Corbin, 1990, p. 72). This analysis technique allows the researcher to analyze the details of the transcripts without overlooking any aspect of participant responses. To do the line-by-line analysis the researcher literally examines the meaning of each line of the transcript and creates codes to capture the information. This is a tedious and time consuming process, and generates a large number of codes.

Line-by-line analysis generates many codes. According to Wiggins (1999, p. 161) this abundance of data is a common issue in qualitative studies, “One of the more pragmatic difficulties that tends to arise in qualitative research is the amount of data acquired, and the subsequent management and processing of these data.” Patton (2002, p. 432) agreed by stating, “The challenge of qualitative analysis lies in making sense of massive amounts of data.” To begin to reduce this large amount of data collected, the researcher will begin to cluster similar codes together into categories. For example, codes like *football, soccer, basketball*, and *baseball* could be grouped into a larger category called “sports.” This process is the next significant phase of data analysis.

Strauss and Corbin (1990, p. 61) define a category as a “classification of concepts. This classification is discovered when concepts are compared one against another and appear to pertain to a similar phenomenon. Thus, the concepts are grouped together under a higher order, more abstract concept called a category.” The categories will be named in the same manner as the codes, except that the category names will reflect their slightly broader, more encompassing nature. Creating categories allows the researcher to see for the first time some of the emergent themes in the data.

“In the course of a grounded theory analysis, one moves from lower-level concepts to higher-level theorizing” (Patton, 2002, p. 491). At this point in the data analysis, the transition will begin from being completely immersed in the data to beginning to conceptualize the data at a higher level. This is the point where the underlying themes of the data begin to present themselves, “The thematic approach to qualitative data analysis involves the development of factors or themes that underlie the information obtained from participants” (Wiggins, 1999, p. 164). Common themes present in the transcripts become evident in the categories created from the codes.

Once the data categories have been established, the researcher will begin to test the strength of the data. To test the strength of the data, a continuum is created for each category. Opposing concepts will be placed at each end of the continuum, and then the data will be plotted on this continuum. It is important to note that this process, while done physically on paper, is not done using any “hard” quantitative metric other than code frequency. The majority of the data will be tested by re-reading sections of the transcript where the data originates and by placing the data on the continuum based on the researcher’s interpretation of the meaning of each particular piece of data. By organizing the data in this way the researcher is able to identify patterns in the data.

Once common patterns in the data are identified, the researcher will begin a cross case analysis of the participant responses. Patton (2002, p. 440) described cross case analysis as “grouping together answers from different people to common questions, or analyzing different perspectives on central issues.” The organization of this analysis will be based on the questions from the interview script. The researcher will analyze the responses from all of the participants to question one, and then question two, etc. The interview script will be created with this type of analysis in mind based on Patton’s advice (2002, P. 440), “if a standardized open-ended interview has been used, it is fairly easy to do cross-case or cross-interview analysis for each question in the interview.” This technique allowed the researcher to explore how participants varied in their responses to the same interview questions. The variation in responses will be included in the interpretation and discussion sections of the study.

At this point in the data analysis themes in the data will be presented, the strength of these patterns tested, and any relationships between the patterns identified. Although on the verge of making assertions based on the data, the researcher will first need to investigate any deviant cases. A deviant case is any data point that strongly opposed the other data points in the same category. This can be thought of as identifying and evaluating outliers in a quantitative statistical analysis. Deviant cases were identified and the cause of their aberration was investigated prior to making the final assertions.

The final step in the data analysis is to make assertions. The assertions will be declarative statements that summarize the data. To make an assertion, the researcher will first define any terms to be used in the assertion, then support the assertion with appropriate quotes from the transcripts, and finally provide his interpretation of the data. The assertions in this study will be the answer to the initial research question.

The data analysis process used in this study is also referred to as content analysis, “Content analysis, then, involves identifying, coding, categorizing, classifying, and labeling the primary patterns in the data” (Patton, 2002, p. 463). Content analysis is a generally accepted method commonly used to analyze textual data. For this study, content analysis can be thought of as a data analysis tool that is used within the theoretical framework of Grounded Theory. In a general sense, “content analysis is used to refer to any qualitative data reduction and sense-making effort that takes a volume of qualitative material and attempts to identify core consistencies and meanings” (Patton, 2002, p. 453). Content analysis is the most appropriate analysis technique for the research question because this method allows the study to contribute to the description of an RLV technician. After all, as Sekaran (2003, p. 409) said, “Description of the matter under study is the main essence of qualitative research and a range of interpretive techniques can be used to decode, translate, decipher patterns, and discover the meaning of phenomena that occur."

One final comment on data analysis; it is important to emphasize that the data analysis process for this study is inductive. Patton (2002, p. 453) explains that,

> *Inductive analysis* involves *discovering* patterns, themes, and categories in one's data. Findings emerge out of the data, through the analyst's interactions with the data, in contrast to *deductive analysis* where the data are analyzed according to an existing framework. Qualitative analysis is typically inductive in the early stages, especially when developing a codebook for content analysis or figuring out possible categories, patterns, and themes.

Grounded Theory is the theoretical framework to guide this study. Inductive content analysis and cross-case analysis will be used within Grounded Theory to analyze the data.

In addition to the interviews, data will be collected from multiple published sources to achieve triangulation. Published sources include: company websites, press releases, conference proceedings, speeches, scholarly articles, and government publications and documents. The data from all of the above sources will be compiled in an effort to present an accurate depiction of each company that is interviewed.

3.7. Researcher Bias

I am a graduate (May 2008) of Purdue's Aeronautical Engineering Technology program. This program prepares students for careers in aircraft design and maintenance. Graduates of Purdue's AET program receive a Bachelor of Science degree, and qualify to take the Federal Aviation Administration's (FAA) tests for mechanic certification. I have successfully completed all examinations and currently hold both an Airframe and Powerplant mechanic's license. I am also a pilot, holding a Private Pilot, single-engine land, license.

I am a graduate student in Purdue's College of Technology. My primary area of study is Aviation Technology, with my related area being Entrepreneurship. My background with Purdue's AET program as well as my experience working as an aircraft technician give me a good idea of the required skills an effective aircraft technician needs. I am familiar with the regulations that guide aviation and the training of aircraft mechanics.

My personal passion in aviation has always been experimental aviation, more specifically homebuilt aircraft. I have always been fascinated with amateur-built kit aircraft. This passion has led me to be an active member of the Experimental Aviation Association (EAA) for many years. My involvement with EAA keeps me on the cutting edge of what is happening in aviation and aerospace. It was this involvement a few years ago that allowed me to witness the dawning of the commercial space industry.

My aviation background and my undeniable interest in the subject area are potential sources of bias. In order to address these, I will do the following throughout my study: include the un-coded and coded transcripts of all interviews in the appendix of the report, explain in detail my data analysis and data reduction processes, and explain my background and experience. Being that I will be analyzing and interpreting the data I collect, these measures are intended to reduce, or at least expose, areas where my personal biases might affect my results.

3.8. Researcher Credibility

In order to perform a robust study I will focus my attention on strengthening my current weakness: lack of experience with qualitative research methods. I plan to focus my energy on a thorough review of literature related to qualitative research, interviewing, and qualitative data analysis. In addition to the review of literature, I will take a qualitative research methods course (EDCI615) as part of my graduate coursework at Purdue. Through the study of qualitative research methods, both in the classroom and out, I hope to develop the required knowledge and skills to establish myself as a credible qualitative researcher and carry out the proposed study.

3.9. Summary

This chapter explained the approach and overall plan of the proposed study. The research framework was discussed and the data collection and analysis processes were described. The researcher's personal biases and credibility issues were also presented.

CHAPTER 4. DATA ANALYSES AND FINDINGS

This chapter presents the data collected for this study. The chapter begins with a discussion of the data analysis process and concludes by presenting the results of the study in the form of assertions that define an RLV technician.

4.1. Sample Attrition

Prior to the discussion on data analysis, attrition of the proposed sample for this study must be addressed. As mentioned in the previous chapter, the sample for this study originally included the following companies:

- *Armadillo Aerospace*
- *Benson Space Company*
- *Blue Origin*
- *Masten Space Systems*
- *Rocketplane Global*
- *Scaled Composites, LLC/The Spaceship Company/Virgin Galactic*
- *SpaceDev*
- *Space Access, LLC*
- *TGV Rockets, Inc.*
- *XCOR Aerospace.*

However, between the time when this study was proposed and when data were collected some of the identified companies became unavailable for participation. In the interest of preserving the anonymity of those that did participate in this study, the sample attrition will be discussed in generalities.

Of the companies listed above, one had come upon difficult financial times and, although still alive in name, was not answering phone calls or emails. It was reported that this company needed an additional $100 million in funding to produce its concept vehicles. The founder of one company passed away, and without him or her, the company dissolved and thus was unavailable for participation. This founder had started another company that was originally identified in the sample, but which had since been acquired by a different company. A representative of the new parent company did participate in the study. One company's website was deactivated, along with all available contact information, prior to data collection for this study. The researcher was unable to locate any other sources of information for this company.

Of the remaining companies, four participated in the study, with one of the participating companies supplying two participants. One company declined to participate, citing International Traffic in Arms Regulations (ITAR) complications as its reason for nonparticipation. One company was interested in participating, but responded to the researcher's inquiries too late to be included in the data for the study. The final company identified in the sample did not participate because the maintenance and operations representative was not available for comment. A total of five participants represented four companies for this study.

4.2. Data Analysis and Reduction

Analysis of the data for this study followed the procedures outlined in the previous chapter. The process included the following steps: multiple readings of the transcripts, open coding, line-by-line analysis, creation of categories of data, testing the strength of the data, cross-case analysis, examination of deviant cases, and development of assertions. Because coded transcripts are provided in Appendix B, the following paragraphs discuss category creation, testing the strength of the data, cross-case analysis, examination of deviant cases, and ultimately the development of assertions.

4.2.1. Category Creation

Creating categories from the codes was the first step in identifying higher-order themes presented in the data. Categories were created to group codes based on similarity. To accomplish this, the researcher created a spreadsheet in Microsoft Excel of every unique code generated during line-by-line analysis and open coding. The spreadsheet was organized by interview and included code name, code frequency, and line number where the code appeared in the transcript. The spreadsheets are included in Appendix D.

To begin organizing this mass of 642 codes, the codes spreadsheet was printed. Each individual code was cut apart so that it was a strip of paper. Included on the strip of paper was the code name, code frequency, and a color-key to identify which transcript the code derived from. Every strip of paper was then laid out so that each paper could be read. At this point, the researcher began grouping similar strips of paper (codes) together. To determine where codes belonged, the researcher re-read the transcripts that the codes came from. Interpretation of the context of each code was used to place it in an appropriate category. The final step of this process was to name each category. All codes were ultimately placed into one of the following categories: Personal Characteristics, Work Environment, Work Experience, and Subject Areas.

The purpose of this study was to determine important subject areas for the training of RLV technicians. Interview questions were designed to identify these important subject areas. Because the funneling technique was used during the interviews, participants began by describing RLV technicians in generalities, then later were guided to narrow their focus to specific subject areas. Although perhaps useful information, the Personal Characteristics, Work Environment, and Work Experience categories do not specifically address the research question (what subject areas are important for the training of RLV technicians?) and did not justify further analysis. Personal Characteristics like *[humility]* or *[attitude]*, and Work Environment attributes such as *[fast paced]* did not seem important to the process of identifying subject area training requirements of an RLV technician. The remaining analysis delved deeper into the Subject Areas category only.

Using the same paper-strip method described above, the researcher further divided the Subject Areas category. The Subject Areas category contained 399 individual codes. These codes were divided into sub-categories including the following: Rocket Propulsion, Aviation Maintenance, Electrical, Mechanical, Engineering, Project Management, and Aerodynamics. The code names and frequencies that are included in each category are included in Appendix E. These seven categories were determined to be the most important subject areas for the training of an RLV technician.

4.2.2. Cross-case Analysis

At this point it was important to determine the strength of the data, and if these seven categories accurately depicted the data. To test the strength of the data a continuum was created for each category. The range of each continuum was labeled “not important” to “important.” Each participant’s responses were then plotted on each continuum based on how important they felt each subject area was. The continuum plots are included in Appendix F.

Cross-case analysis was also accomplished by plotting the participant responses on each continuum. Plotting each participant’s feedback across each subject area allowed for a comparison of all participant responses. The proposed cross-case analysis *by question* was replaced by cross-case analysis *by subject area* because the researcher felt this more accurately addressed the research question, and more appropriately tested the strength of the data. Cross-case analysis revealed a logical rank-order of the Subject Area sub-categories based on the strength of each sub-category. The researcher concluded that sub-categories that were identified as important to multiple participants, and had a high number of code frequencies, were stronger than those with fewer participants and code frequencies. Stronger sub-categories were classified as higher-ranking, or more important.

Prior to examining deviant cases and stating the assertions, as a final component of cross-case analysis, the job functions of the participants of this study were considered. The participants in this study ranged in job function from RLV technician to RLV company founder. In no particular order, participant job functions for this study included: Engineer, Vice President of Operations, RLV Technician, Company Founder, and Engineer. This breadth of participant job functions provided a large spectrum of backgrounds, perspectives, and experiences that contributed to the rigor of this study.

4.2.3. Deviant Cases

The final step before creating assertions was to identify and examine any deviant cases. To identify deviant cases the researcher reviewed all the codes in each of the seven Subject Area sub-categories for any codes that seemed out of place. The following codes were identified as deviant cases: *[chemistry]*, *[gas turbines], [physics]*, and *[construction skills]*. The following paragraphs justify why each of the above was identified as a deviant case, and provide an explanation of why the deviation occurred.

The *[chemistry]* and *[physics]* codes were located in the Rocket Propulsion and Aerodynamics sub-categories, respectively. These codes were identified as deviant cases because they identified an area of academic study, whereas the overwhelming majority of the other codes identified an applied demonstration of knowledge. These were two codes that identified the root subject area as taught in school versus the application of learned knowledge on the job, or in a specific situation. The context of *[chemistry]* was propellant handling, a subset of rocket propulsion, and thus can be interpreted to mean an applied general knowledge of chemistry to propellant handling. The context of *[physics]* was in reference to a general knowledge of aerodynamics and engineering. Neither of these deviant cases significantly affected the strength of their sub-categories.

The *[gas turbines]* code was located in the Rocket Propulsion sub-category. This code was identified as a deviant case because by definition

Rocket Propulsion does not include gas turbine engines. Rocket engines use their own supply of oxygen or oxidizer to support combustion whereas gas turbine engines rely on the earth's atmosphere as its source of oxygen to support combustion. The context of *[gas turbines]* was a discussion of the general knowledge an RLV technician should have, and was likely in reference to the similarity between aviation maintenance and RLV maintenance. This deviant case did not significantly affect the strength of the Rocket Propulsion sub-category.

The *[construction skills]* code was in the Mechanical sub-category. This code was identified as a deviant case because only one participant discussed these skills. The *[construction skills]* referred to those skills that are necessary to build residential houses or commercial buildings. The context of this code did fit into the Mechanical sub-category, but because this specific type of skill was only mentioned by one participant it was determined to be a deviant case. This deviant case did not significantly affect the strength of the Mechanical sub-category.

4.3. Findings

The final step of data analysis was the development of assertions. Assertions presented the findings of the study, and answered the research question this study originally proposed to investigate. The assertions were created using the following format: assertion, definition of terms used in the assertion, supporting data from transcripts in the form of quotations (verbal stalls, pauses removed by the researcher for clarity), and the researcher's interpretation or clarifying remarks about the assertion.

The assertions were based on the Subject Areas sub-categories. They were arranged in numerical rank-order based on the strength of the data determined by cross-case analysis. To determine the order of importance, emphasis was placed on the number of participants that discussed the sub-category and the number of codes generated within each sub-category. The supporting data including code names and code frequencies, color-coded by transcript, are included in Appendix E.

4.3.1. Assertions

1. **Rocket Propulsion is an important subject area for the training of RLV technicians.**

Definition – Rocket Propulsion was an overarching term used to group codes related to rocketry, propellant handling, and plumbing. Rocketry refers to the specific study of rocket engines. Propellant handling refers to the loading and unloading of rocket fuels, oxidizers, cryogens, propellants, chemicals etc. Plumbing refers to the system of pipes and valves that controls and delivers fuels, propellants, oxidizers, etc. to various components on an RLV.

“I think they need to know what a standard airplane technician knows, plus know about rocket systems and how they work, and a basic understanding of the chemicals and pressures involved with them” (Participant 2, 2010).

“If they know high pressure plumbing, and if they’re comfortable working around several thousand PSI that’s a big plus, too” (Participant 2, 2010).

“Rocketry is plumbing. Making a launch vehicle is essentially plumbing” (Participant 4, 2010).

“Rocket systems are mainly plumbing oriented” (Participant 5, 2010).

“Oxidizer handling and safety is one of the biggest ones that we spend a lot of time having to train them. If they came in already trained on oxidizers, that would save a significant amount of time” (Participant 2, 2010).

“For the most part, the RLV technicians are going to be in direct contact with propellant loading and unloading, and then pressurization and depressurization” (Participant 5, 2010).

Interpretation – Rocket Propulsion was the most important Subject Area sub-category. Every participant discussed various aspects of rocket propulsion, and most mentioned it specifically. Rocket propulsion was also discussed the most heavily as reflected by the large frequency of codes (188) related to this subject.

Rocket Propulsion could be further divided into three categories: Rocketry, Propellant Handling, and Plumbing. Each of these groups could have been stand-alone categories, but were so closely related that they were grouped together. Rocketry consisted of codes such as *[rocket propulsion], [rocketry]*, and *[propulsion specialist]*. Propellant Handling consisted of codes such as *[oxidizers], [propellant handling], [chemicals]*, and *[materials compatibility]*. Plumbing consisted of codes suck as *[plumbing], [high pressure systems],* and *[fittings].* It is important to make sure that these topics are included when discussing the overall sub-category of Rocket Propulsion.

2. **Aviation Maintenance is an important subject area for the training of RLV technicians.**

Definition – Aviation Maintenance refers to the training required by the Federal Aviation Administration for an aircraft Airframe and Powerplant (A&P) Mechanic.

"I mean a lot of the (RLV) systems just aren't that different from a traditional plane" (Participant 2, 2010).

"There already is a standard technician for a regular airplane…a lot of the systems transfer over (to an RLV). I mean life support is more complex, but the basics are there" (Participant 2, 2010).

Interpretation – All of the participants discussed an Aviation Maintenance background, and many participants indicated they would prefer their RLV technicians had their Airframe and Powerplant Mechanic's license. Some stated specifically that aviation maintenance experience directly applied to their RLVs, whereas some pointed out that the broad knowledge base acquired from an aviation maintenance background would be beneficial to an RLV technician.

Skills in the areas of troubleshooting and diagnostics were identified as important by participants. Overall system knowledge was mentioned as an important aspect of an RLV technician by multiple participants.

3. **Electronics/Electrical Systems is an important subject area for the training of RLV technicians.**

Definition – Electronics/Electrical Systems refers to all systems on an RLV that use electricity or electrical signals.

"I think the two most important systems that an RLV technician should be familiar with is electronics and plumbing" (Participant 4, 2010).

Interpretation – All of the participants thought electronics or electrical systems knowledge was important to being an RLV technician. Electrical in this sense included codes ranging from *[wiring]* to *[avionics]*. The overall consensus was that electronics are an integral part of any RLV, and thus an RLV technician must be knowledgeable of electronics and electrical systems.

4. **Mechanical Systems is an important subject area for the training of RLV technicians.**

Definition – Mechanical refers to an understanding of machines and how they work.

"The point is that the technicians have to have strong mechanical skills no matter what. And then we'll get specific from there" (Participant 1, 2010).

Interpretation – This category embodied the typical characteristics of a technician including and understanding of component fabrication, assembly and disassembly, and composite materials as well as skills like welding and machining.

5. **Engineering is an important subject area for the training of RLV technicians.**

Definition – Engineering refers to the practical application of abstract concepts like mathematics, science, and technology.

"We look for all around engineering and problem solving skills" (Participant 3, 2010).

"Mechanical engineering in general, except for when you get into electrical engineering. Those two areas, if you get the basics of those, the rest of it can be taught and learned" (Participant 3, 2010).

Interpretation – Many participants wanted their RLV technicians to be familiar with the basics of engineering as it applies to an RLV. Less emphasis was placed specifically on aerospace engineering, rather on general engineering fundamentals. An understanding of the overall engineering process and having a technician that could be involved in the design process was also important to the participants.

6. **Project Management is an important subject area for the training of RLV technicians.**

Definition – Project Management refers to an understanding of how an RLV is designed and evolves throughout its life cycle. Project Management also refers to process and procedure development and maintenance.

"Project management" (Participant 3, 2010).

"Understanding that your deliverables effect the company, and effect other deliverables and understanding the process of building an RLV is just as much an engineering process as actually bending the metal and figuring out the-the-the problems" (Participant 3, 2010).

"The ability to look at the overall path and anticipate the needs along the way and set up planning, i.e. if there's a procurement of equipment, to see to it that that equipment can get you through a few if not several iterations of your design process” (Participant 4, 2010).

Interpretation – Project Management was stressed heavily by a few participants as important subject areas for the training of RLV technicians. Project Management included the creation of procedures and processes by the RLV technicians, and the monitoring and updating of procedures as an RLV matures. Participants wanted their RLV technicians to be involved in the planning, forecasting, and logistics of their RLVs. Participants also wanted RLV technicians to be aware of continuous improvement techniques and be constantly mindful of ways to improve their designs and processes.

7. **Aerodynamics is an important subject area for the training of RLV technicians.**

Definition – Aerodynamics refers to the study of the flow of gases.

“Aerodynamics would be a good healthy area to get some familiarity in” (Participant 4, 2010).

“What I need is someone who understands the aerodynamics of both subsonic and supersonic” (Participant 1, 2010).

Interpretation – Some participants wanted their RLV technicians to have a basic understanding of Aerodynamics. The emphasis was less on the advanced mathematics of aerodynamics, but rather on the importance of understanding both subsonic and supersonic, or hypersonic, aerodynamics and how they apply to an RLV.

4.4. Summary

This chapter presented the process used to analyze the data gathered for this study. The data used for the study is included in various appendices. The results of the study were presented and briefly discussed.

CHAPTER 5. CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

This chapter summarizes the research project and comments on the results. Included in this chapter is a discussion of the study as well as the researcher's recommendations and suggestions for future research.

5.1. Conclusions

The purpose of this study was to identify subject areas that are important for the training of RLV technicians. This study sought to contribute to the body of knowledge related to commercial sub-orbital RLV operations and maintenance by further defining the RLV technician. The background of the study was based on literature including publications from RLV companies, academia, and the United States government.

This was an exploratory, qualitative study framed by Grounded Theory and Reality-Oriented Correspondence Theory. The sample for this study was selected purposefully using maximum variation and criterion-based sampling techniques. The participants of this study consisted of five maintenance and operations representatives from four U.S. based RLV companies. Data was collected via in-depth interviews conducted through a telephone by the researcher. The interview questions and interview protocol were created by the researcher with the guidance of subject matter experts in aviation maintenance, rocket propulsion, qualitative research, and curriculum development. The data collection instrument and procedures were validated by a pilot-study prior to conducting this study. Data used in this study was collected, transcribed, analyzed, and presented in a written report by the researcher.

This study identified the following subject areas as important to the training of RLV technicians:

1. Rocket Propulsion
2. Aviation Maintenance
3. Electronics/Electrical Systems
4. Mechanical Systems
5. Engineering
6. Project Management
7. Aerodynamics

These seven areas were presented in order of importance; Rocket Propulsion being the most important subject area, Aerodynamics the least important. The ranking of subject areas was established by the researcher based on the number of participants who discussed each subject area and the researcher's interpretation of the emphasis each participant expressed related to each subject area.

5.2. Discussion

Although the results of this study might not have been entirely surprising, there were a few particularly remarkable points. Most notable was the lack of any discussion, or even mention, of the FAA/AST RLV operations and maintenance guide. Although the FAA/AST guide was still a work in progress during this study, it remains surprising that no participant mentioned it at all. As stated earlier, the FAA/AST guide presented three possible training programs that RLV companies could use as models for RLV technician training including: the FAA Airframe and/or Powerplant Mechanic, SpaceTEC Aerospace Technician Certification program, and the Automotive Service Excellence Certification. Of these three potential RLV technician training models, only the FAA Airframe and Powerplant Mechanic program was mentioned, and it was emphasized by all participants.

It was surprising that SpaceTEC was never mentioned because this program was designed specifically for aerospace maintenance technicians. This might imply that the RLV companies are unaware of the SpaceTEC program, or that perhaps it is not meeting the needs of these companies. There was also no mention of an existing training program or school from which the RLV companies get their technicians. This suggests that a niche may exist for a training program focusing on RLV technicians.

As discussed earlier, the researcher sought to triangulate the findings of this study by comparing them to published literature from industry, academic, or governmental sources. Many articles and documents were examined from a wide variety of sources, but ultimately the most thorough description of an RLV-like technician was found in the Crew Chief job description from the Rocket Racing League's website. The job description is included here in its entirety:

> **Crew Chief**
> The Rocket Racing League seeks a fearless hands-on crew chief to join our team to break new ground in aviation and aerospace. An experienced and licensed A&P with stamina for extensive on-the-road field operations, the ideal candidate is comfortable working with avionics, airframes and rocket propulsion systems. Whether laying up a composite air duct to create positive pressure inside the aft engine cowling, installing a transponder system or leading ground operations in support of flight tests to expand the operating envelope of the League's own Rocket Racer, the crew chief is successful in assuming multiple roles and having a significant positive impact on the growth of the company. The candidate will join the league in a key hands-on capacity as the League expands its fleet of production-level Rocket Racers and continues to launch the world's freshest and newest sport enabled by a suite of patented high power technologies unlike any other. This position reports directly to the CTO, works closely with RRL chief pilot, staff from RRL wholly owned subsidiary Velocity, Inc., and staff from engine provider Armadillo Aerospace, as well as other strategic partners.
> **Essential Duties & Responsibilities:**
> Lead all airframe operations, including but not limited to, assembly/disassembly, maintenance, troubleshooting, basic design work, basic composites construction, avionics installation and wiring, engine/airframe integration, engine installation/removal, transportation of airframe and engine module, vehicle inspection for flight readiness, maintenance of aircraft logs in accordance with FAA and RRL requirements, training, documentation and interface with air show and race venue officials.

1. Perform maintenance of aircraft in accordance with applicable regulatory, manufacturer and company regulations, policies and procedures.
2. Maintain aircraft to the highest standards possible.
3. Maintain ground support equipment, and work areas in a clean and organized manner.
4. Ensure timely acquisition of parts, tooling and equipment.
5. Schedule maintenance in an efficient and organized manner which maximizes aircraft availability.
6. Perform maintenance record entries in accordance with applicable FAA, manufacturer and company policies and procedures.

Secondary responsibilities will be in support of overall Rocket Racer operation, including but not limited to sourcing, storage, handling and loading/unloading of propellants and pressurants; fielding Rocket Racer operations under R&D, exhibition or air race FAA certificates; maintenance of Rocket Racer including airframe, avionics and propulsion systems.

Requirements:

1. FAA Airframe and Powerplant Certificate (A&P) as prescribed by FAR 65.
2. Applicant must meet recent experience requirement of FAR 65.83.
3. Familiarity with liquid rocket propulsion systems
4. Familiarity with advanced avionics and virtual/augmented reality systems
5. High School graduate or equivalent.
6. 5 years aviation maintenance experience.
7. Desire and ability to work as a team with flight, engineering and marketing
8. Ability to work overtime hours as needed, including days, nights, and weekends to complete maintenance.
9. Must be available for extended travel
10. Helpful, though not mandatory, is experience with Challenger 600 jets.

If you are such a candidate and this sounds like a role you will excel and enjoy please submit a cover letter with your salary requirements and resume to careers@rocketracingleague.com

The above job description required six of the seven subject areas that were identified by this study including: Rocket Propulsion, Aviation Maintenance, Electronics/Electrical Systems, Mechanical Systems, Engineering, and Project Management. The only subject area not specified by the job description was

Aerodynamics, the lowest priority subject area this study identified. This suggests that the findings of this study are in alignment with the needs of the RLV industry.

5.3. Recommendations

Based on the results of this study, an ideal RLV technician would not only have a background in aviation maintenance, but would also have knowledge of Rocket Propulsion, Engineering, Project Management, and Aerodynamics. This study suggested that an FAA certified Airframe and Powerplant mechanic with aviation maintenance experience could provide a strong base from which to prepare an RLV technician, given that an Airframe and Powerplant mechanic would have knowledge of three of the top four subject areas identified by this study as important in an RLV technician including: Aviation Maintenance, Electronics/Electrical Systems, and Mechanical Systems. The remaining subject areas could be taught through additional training programs or additional coursework at an aviation maintenance training facility.

It is the researcher's opinion that the ideal RLV technician training environment is a four-year Aeronautical Engineering Technology or Aviation Maintenance Technology program. These aviation technology programs are based on the training requirements of an FAA Airframe and Powerplant mechanic, yet offer the opportunity to incorporate additional material coursework into their curricula. An RLV technician minor, or area of concentration, could be developed based on the subject areas identified in this study. An RLV technician minor could serve as an initial effort to train an RLV-focused aerospace maintenance technician.

For example, Purdue University's Bachelor of Science in Aeronautical Engineering Technology would be an ideal testing ground for the RLV technician program. This curriculum has been developed around the FAA Airframe and Powerplant mechanic's license, but has evolved to include coursework related to engineering and project management. This program's affiliation with Purdue University and Purdue's Zucrow Rocket Propulsion Laboratory enables coursework to be added outside the area of Aeronautical Engineering Technology, such as Rocket Propulsion, Engineering, Project Management, and Aerodynamics. Courses could be added based on the results of this study to create an RLV technician well versed in Rocket Propulsion, Aviation Maintenance, Electronics/Electrical Systems, Mechanical Systems, Engineering, Project Management, and Aerodynamics.

It is recommended that Purdue University take the lead in RLV technician training because of its Aeronautical Engineering Technology curriculum, faculty, and facilities, as well as its access to Zucrow Rocket Propulsion Laboratory. To accomplish this, an RLV technician training curriculum should be developed as an additional area of study to Purdue's Aeronautical Engineering Technology program. Select members of Purdue's Aeronautical Engineering Technology faculty should work with subject matter experts at the companies in the RLV industry and Zucrow Rocket Propulsion Laboratory to develop this program. The RLV companies could provide continued insight regarding their technical needs, as well as provide internships and potentially full time employment for students participating in the RLV technician training program. The goal of this program would be recognition as a successful developer of RLV technicians by the RLV industry, and perhaps recognition by the FAA/AST. Once the RLV technician training program has evolved and matured, a formal license or endorsement to the FAA Airframe and Powerplant mechanic license could be a final milestone. At that point, other institutions interested in developing RLV technician training programs could duplicate these efforts and create their own RLV technician training programs based on the established curriculum.

It will be necessary to conduct follow-up studies to verify that the subject areas identified by this study indeed represent the important subject areas for the training of an RLV technician. In addition to high-level verification, research will be required to determine what specific knowledge, skills, and abilities are required within each subject area. Additional research will be necessary to determine if the subject areas for RLV technician training identified by this study are also important or relevant for orbital RLVs, as this study focused on sub-orbital RLV technicians. There are many questions that require answers through a combination of research and experience to fully develop an RLV technician training curriculum. There is a significant need for further research regarding RLV maintenance and operations.

5.4. Summary

This chapter provided the researcher's insights regarding the findings of this study. The study was summarized and findings were discussed. The chapter concluded with the researcher's recommendation of what to do with the results of the study and provided suggestions for future research.

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APPENDICES

Appendix A. Interview Transcripts

Date:	1/29/2010
Time:	4:05PM
Interviewer:	Brent Vlasman
Interviewee:	Participant 1 (P1)

Brent - OK this is Brent Vlasman interviewing P1 for the reusable launch vehicle technicians project. I'm going to go ahead and read the opening statement…and I just want to have on record P1, that I do have your permission to record this?

P1 – Yes, you do have my permission, my name is P1 and I'm with Company ABC.

Brent – OK thanks. I'll read this, and then we can start with the questions…

P1 – OK.

Brent – Um, Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle (RLV) technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, do you have questions before the first question?

P1 – Nope!

Brent – Nope, ok, so question one: What do or what did you look for in hiring your future or your current technicians?

P1 – Ok, this applies both to past, present, and future.

Brent – Ok.

P1 – The first thing we look for is attitude.

Brent – Ok.

P1 – Umm…the type of attitude that a person has, uh, the RLV companies, Company ABC is one, Company ABC is another, Company ABC, Company ABC…we're breaking new ground and we need people who are willing to break new ground. In other words, we have interviewed people who have been in one industry for 10-15-20 years and their, ah, attitudes are set towards a certain way and if you say, 'well let's try it a little bit different way' they will balk.

Brent – Hmm.

P1 – So, ah…frankly what we look for is people who have ah, an attitude that is, 'Ok, I've got some experience in something else, let's try it.' For instance, the gentleman who is our chief engineer started out designing submarines. The gentleman who is in charge of our shop was the top diesel mechanic at a truckstop.

Brent – Hmm.

P1 – So…we look for…not aerospace experience per se, or even airplane experience per se, but an attitude that wants to do this.

Brent – Ok.

P1 – That's the first thing we look for. The next thing we look for is experience. Ah…and even in interns, and we do take college interns…we encourage college interns. We want to look for people who have had experience in life…say our senior engineer grew up in a machine shop, his dad owned a racing comp…ahh…group, so he grew up with racing cars…

Brent – Ok…

P1 – Therefore he understands both high performance mechanics and…he gained a personal eye to the dangerous or…difficult situation. Does -does that help you at all?

Brent – Yeah, no this is good – the only reason I'm not talking I'm taking some notes while we're going through this…

P1 – Sure, sure.

Brent – Ok, so you look for attitude, and maybe some flexibility in there…right now I'm just kinda paraphrasing you, correct me if I'm wrong.

P1 – Sure, uh huh…

Brent – And in the experience is there…um…uh, hands on type experience?

P1 – Yeah…

Brent – You said machine shop and racing and stuff like that?

P1 – Yeah, we look for hands on experience. Someone who has, uh, sat at a computer, or who is…what we like to call a-a-a 'me too-er', in other words 'hey that's a good idea', 'yeah me too I think that's a good idea' is-is…they just, they're nice people…but they just don't have the experience we need. For instance, if we need something welded, I'm out in the welding shop. Uhh…if we need the bathroom cleaned sometimes the president of the company goes and cleans the bathroom…uh…you have to flexible, you have to understand you need to do different things.

Brent – Mhm.

P1 – Uhh…in order to get the job done.

Brent – Ok. Do you have anything else that you look for in – in hiring your technicians?

P1 – Hmm…let's see…attitude, experience, ability, oh…a knowledge of your own limitations.

Brent – Ok…

P1 – That's very important. Uhh…it…if someone doesn't understand that they don't understand something, they can kill people.

Brent – Ok.

P1 – And…we don't to have…and we have had to…uh…let people go who didn't understand their own limitations.

Brent – Ok. I think that's a good segue into the second question, it's knowing your limitations so what additional knowledge areas would you like your technicians to possess?

P1 – Oooh…I don't want to pin anything down because we have…we found that, ya know, somebody who…uh…worked on a really weird, uh, pump 25 years ago, that has turned suddenly relevant to what we are doing. Uh we have a guy who uh…we had a guy…our chief machinist as a matter of fact…works on steam locomotives…

Brent – Hmm...

P1 – And his experience is directly relevant to some of the rocket engine parts that we make.

Brent – Really?

P1 – So…additional knowledge…I-I can't specify.

Brent – Ok, that's fine…ya know…

P1 – Yeah…

Brent – Any answer is ok…there's no right or wrong here…

P1 – No I understand that, it's just…thinking about it…you always like um, people to have say…the knowledge of certain computer programs like CATIA, or…MATLAB…or SolidWorks…that's real helpful…

Brent – Mhm…

P1 – Um…I hadn't even thought about the electronics side of it…cause we're…since we're about half electronics and half mechanics. In other words – we'll design something on a computer and then we'll go building it.

Brent – Ok.

P1 – Yeah, a-a-a good computer grounding obviously is-is important.

Brent – Ok. Anything else for that?

P1 – Huh uh.

Brent – Ok, it sounds like it's kind of a broad skill set and that's kinda hard to pin down, you know…

P1 – It is! It is….well especially because we're…we're breaking new ground. Uh…ya know with an established, mature industry like the airline industry they can name exactly what they need…

Brent – And they do…

P1 – We're not…yeah, and we're not there yet. Ya know, we're still not floundering, but you know, we're still chopping the weeds…

Brent – Ok. Um, I'll move on to question three then…

P1 – Uh huh.

Brent – What systems or subsystems should RLV technicians be familiar with?

P1 – Ok now, are you talking about hiring a new person? Or someone who…after he's hired?

Brent – It could be either…I'm really looking for the total knowledge base of an RLV technician.

P1 – Ok, well…I-un-unfortunately which RLV are you talking about? Haha…

Brent – Haha…well…yours I guess…

P1 – Ok…haha…let's specify ours because just as there are semi-trailer trucks as well as two seater sports cars…

Brent – Mhm…

P1 – You're gonna have the same, ah…diversity in-in launch vehicles.

Brent – Right…

P1 – So, ours looks like an airplane. We can't call it an airplane, but it looks like an airplane. So what I need is someone who understands the aerodynamics of both subsonic and supersonic.

Brent – Ok.

P1 – Ah…someone who understands ah, composites.

Brent – K.

P1 – And- and how to work with them. Uh…geeesh…there are going to be folks like, just like A and P's, there are gonna be folks who specialize more on the engines side, than the airframe side.

Brent – Ok…so maybe an engine or propulsion specialist?

P1 – Yeah, propulsion specialist and again we're gonna have to train them from scratch…

Brent – Right…

P1 – Pretty much…our engines are different from Company ABC's engines are different from Company ABC's are different from Company ABC's…so…

Brent – And that's why you have to train them from scratch?

P1 – Just about. Also, I don't think it's like learning airplane engines in 1900.

Brent – Mhm.

P1 – There weren't any…ok?

Brent – Mhm.

P1 – They were struggling to get some…it wasn't until you had a half-way decent-decent engine that you could get heavier than air flight. Um, and there were a lot of different engines and there were a lot of different technicians working on them. Uhh…what did Manly work like what five years on that engine that Langley used? And the point-the point is that…um…the technicians have to have strong mechanical skills no matter what.

Brent – Ok.

P1 – And then we'll get specific from there.

Brent – Ok. Um, so…a-a general mechanical aptitude…

P1 – Yeah...

Brent – Is what you're looking for?

P1 – Yeah, yeah. And if they've had some physics and chemistry so that they know not to mix, you know, tryiline and hydrazine together, that'd be nice…but since we don't use those chemicals anyways ok, but a-a-a-basic understanding of chemistry is really good. And you need for that life anyways so…

Brent – And is that something that you train your people on…or you would…is the basics of chemistry? Or do you kind of…

P1 – Oh yeah…we not only train them on that, we train them how to write. We train them English…

Brent – Ok.

P1 – Uh…that's another…back up to number, ah, number two…

Brent – Mhm.

P1 – I-I should have mentioned this…is we need very strong, good English skills.

Brent – Hmm. Ok.

P1 – Well…a misplaced comma can kill somebody.

Brent – No, that makes sense…

P1 – Yeah, so…we-we need good English and good writing…

Brent – Good English and communication?...

P1 – Uh huh.

Brent – Ok…um…anything else for systems and subsystems that you can think of?

P1 – Mm….not right off.

Brent – Ok. Question number four:

P1 – Uh huh.

Brent – If you started with a clean slate, in your opinion what are the most important subject areas for an RLV technician to be familiar with?

P1 – Ok, chemistry.

Brent – Chemistry.

P1 – Physics.

Brent – Ok.

P1 – Uhh, basic engineering.

Brent – What do you mean by basic engineering?

P1 – Well…uh…understanding umm, that uh…different fasteners are needed for different applications. In other words, uh…you don't use a bolt where a rivet will do…

Brent – Ok.

P1 – Umm…you, I mean…stuff you get in engineering 101…

Brent – Ok, so you have…loads, and statics dynamics…

P1 – Yeah…

Brent – That type of thing…

P1 – A little bit yeah….and some, practical stuff.

Brent – Ok…

P1 – Let's see…a little bit of avionics would be helpful.

Brent – Ok, and is that aviation-like avionics, or is this?...

P1 – Yeah, yeah-yeah…

Brent – Ok.

P1 – Aviation. Yeah we try to…everybody who's here we encourage to fly…

Brent – Ok…

P1 – And we have, uh…private pilots here, and people who own their own airplanes and it's not that we're airplane fanatics, but the more you fly the more you understand regime that you're working in.

Brent – Right, that makes sense.

P1 – Yeah so pilot's license would be nice.

Brent – Ok.

P1 – One of the things Company ABC does which is really great, is they require their engineers to have built an airplane.

Brent – Hmm.

P1 – And we don't require that, but um…if somebody says 'hey I'm working on an airplane' or 'I designed and built model airplanes and flew em' or 'hey I designed and built a submarine' that would be good. That-that's really highly desirable.

Brent – Ok, so you look for homebuilding experience of some sort?

P1 – Yeah – yeah even if it's a racecar, or models, or whatever…homebuilding is-is…

Brent – Ok.

P1 – Desirable, yeah.

Brent – Ok…so…just looking at my notes…chemistry, physics, and the basics of engineering…avionics and then some homebuilding or flight experience…

P1- Yeah…

Brent – Anything else that you'd like, um, subject wise, them to be familiar with? Again…this is in the ideal world…money is no issue…

P1 – Yeah…hahahaha…well they oughtta get all the movie references – Buckaroo, Bonzai, Star-Wars, that kinda thing…but uh….

Brent – Movie references…ok…hahaha…

P1 – Hahaha…well we take our job very seriously, but we don't take ourselves seriously, and we like to joke around…

Brent – Ok…

P1 – And you know, somebody picks up…a finger protecter and goes 'exterminate! Exterminate!'…everyone gets the reference…so…

Brent – Right…haha ok so…I gotta have movie training on there…haha

P1 – Yeah…hahahaha.

Brent – Ok, is that all that you can think of for…ah…subject areas?

P1 – Yeah…

Brent – Ok. And if there's anything…ok so here's kinda the catch all question number five…

P1 – Uh huh…

Brent – With regards to reusable launch vehicle technicians, what have we not discussed that you feel is important?

P1 – Hmm…They're going to have to have a toleration of government intervention.

Brent – Ok. What do you mean by that?

P1 – Alright…hey you're an A and P, right?

Brent – Correct.

P1 – Ok…the FAA can be a real pain in the neck.

Brent – Ok.

P1 – And occasionally…I know even dealing with them when I get my medical…whose neck do I wring, ok? I'd love to be Darth Vader ever once in a while 'I find you're lack of faith disturbing'…

Brent – Hahaha…

P1 – But ahh…haha..it would get things done…because ah, once again, RLVs are breaking new ground, we have to train the regulators.

Brent – Ok.

P1 – In what we're doing…and explain to them that what we're doing is not going to cause the demise of western civilization as they know it.

Brent – Ok.

P1 – Which they occasionally think we are. So you have to have…a certain degree of tolerance of explaining things to them and – and realizing they're really trying to help, they just don't want you to have a bad accident when they're in charge.

Brent – Right, ok.

P1 – So, uh…a certain amount of being able to sit back and realize and explain to ignorant but interested people what you're doing is helpful.

Brent – Ok, so some patience for dealing with…

P1 – Patience…

Brent – With the regulatory agencies?

P1 – Yeah…yeah.

Brent – Ok. Anything else that you'd like to mention that I didn't necessarily ask you specifically?

P1 – Ohh….I'm trying to think…um…once again, I'd like to emphasize that all these launch vehicles are different.

Brent – Ok.

P1 – So what's good for one is not necessarily going to be helpful for somebody else.

Brent – Right.

P1 – Um…ya know, if-if a top engine guy from say, Roush or one of the other uh…racing car companies came to me and said I want to work for you I'd hire him in two seconds.

Brent – Why is that?

P1 – Or if…because he's got a tremendous amount of experience dealing with harsh environment, for the-the mechanics of what they're doing…

Brent – Mhm.

P1 –Umm…uhh…doing new and different things, and making sure that the people who are using these new and different things are going to be ok, that they're going to be safe….

Brent – Ok…so it sounds like, and I don't wanna put words in your mouth, so don't let me…um.. it's kind of an attitude of flexibility and safety consciousness, moreso than…ya know, 'thou shalt have this many hours of this experience on this…'

P1 – Correct…yes-yes that is correct. When we hire people, we don't necessarily look at their grades, and we don't necessarily look at their degree. We hired a-a-business major once as a junior engineer and it worked out really well. And he became a really good engineer, lousy business major but a really good engineer…haha. Ah- again it was his…it was his enthusiasm and his attitude as well as his mind…

Brent – Mhm.

P1 – Um…and ah he…he went ahead and got his business degree and then became an engineer and I think he's working for Company ABC now…he's one of their junior engineers over there now.

Brent – Ok. So with your technicians you're less focused necessarily on technical competency, more on the…attitude and-and character of the person?

P1- Yeah…

Brent – At least right now…

P1 – Yeah, character is real important.

Brent – Ok.

P1 – Once again, if you lie you're gonna kill people. So…

Brent – Yeah…

P1 – We have to make sure that our people are…trustworthy, honest, brave, thrifty, whatever else it is that the scout's motto is…hahaha…

Brent – Hahah…is there anything else that you'd like to add that I haven't got to ask you yet?

P1 – No…I think, think we've pretty much done it here…if you're happy?

Brent – Oh I'm happy…um…

P1 – Ok.

Brent – Then I'm gonna go ahead and end this recording. This ends the interview with P1 of Company ABC, and it is what…January 29th, of 2010.

P1 – Yep.

END RECORDED INTERVIEW

Date:	2/3/2010
Time:	3:45PM
Interviewer:	Brent Vlasman
Interviewee:	Participant 2 (P2)

Brent – Ok the recorder is going. Um this is Brent Vlasman, this is the interview with Participant 2 for the reusable launch vehicle maintenance project. And I do have your permission to record this, Participant 2?

P2 – Yes, you do.

Brent – Ok, then I will go ahead and get into the interview protocol, read this opening statement, and then we'll start with the questions. So the opening statement is: Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle or "RLV" technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation, um Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, do you have questions before I get in to the actual interview questions?

P2 – Nope.

Brent – Nope, ok. And if you do, I mean, you can just ask along the way and I will clarify if something is unclear.

P2 – Ok.

Brent – Ok, so question number one: what do or what did you look for in hiring your future or current technicians?

P2 – Um, well generally just a-a broad knowledge base. Um, the more they can do the better. Um, ya know, we typically have to…the the the one thing that ah, you know, that will be significantly different in these systems that will, like current airplanes and such, is a large amount of oxidizers are stored on these vehicles. Um, so familiarity with handling of oxidizers is a big plus…

Brent – Ok.

P2 – And if you can find someone who's trained.

Brent – Ok, and when you said the more they can do the better what types of things did you mean?

P2 – Hmm, um, well a technician is plumbing and electrical and troubleshoot, and you know, you basically you can point them at a problem, and have them fix it and know that they're, ya know, qualified to fix it, ya know, that's great…especially in R and D programs, they can do a little bit of everything…from electrical to plumbing, um, to torqueing bolts and that kind of thing.

Brent – Ok.

P2 – But, ya know, specifics…we have to…the systems are going to be specialized, and there will have to be specialized training for each vehicle.

Brent – Ok.

P2 – But the general broad knowledge base is about the best.

Brent – Ok, um…what additional, so this is the second question, what additional knowledge areas would you like your technicians to possess?

P2 – Oxidizer handling and safety is one of the biggest ones that we spend a lot of time having to train them. If they came in already trained on oxidizers, um, that would save a significant amount of time.

Brent – Ok, is that something that you do internally, or is there some place that you…subcontract that training? Or…

P2 – We do that internal, um…so that we can…there's places you can contract out, um…NASA has a training program, um, on oxidizers…um, and I think even out of, um…the…I can remember which base it is in New Mexico…but I'm pretty sure that they're the ones with the oxidizer training and handling course…um…

Brent – Ok, so knowledge of oxidizers and handling them?

P2 – Mhm.

Brent – Is there anything else?

P2 – Not really, I mean a lot of the systems just aren't that different from, ya know, a traditional plane.

Brent – Ok.

P2 – Um…for the basic knowledge skill set.

Brent – So are you assuming…

P2 – I mean how…

Brent – Oh I'm sorry, go ahead…

P2 – How everything is implemented is different, but you know, a lot of what's there, ya know the landing gear doesn't change if you've got wheels, you know…things like that don't change…

Brent – Right…

P2 – It's just that you-you're dealing, the biggest thing is you're dealing with different chemicals on board…

Brent – Right, and so are you, kind of coming at it as if the person has a baseline in aviation maintenance?

P2 – Yeah, if they do…

Brent – Ok.

P2 – Ya know, adding in oxi-oxidizer training and the other thing is high pressure systems.

Brent – Ok, high pressure systems.

P2 – If they know high pressure plumbing, and you know, if they're comfortable working around, you know, several thousand PSI that's a big plus too.

Brent – Ok. What systems or subsystems should RLV technicians be familiar with?

P2 – Well, a basic understanding of – of rocketry and jet engines is, ya know, key. They don't have to be able to design one, but they need to know the basic components and the parts. Um, you know, just as they would for someone who works on a piston driven engine.

Brent – Ok. Um, any other systems or subsystems…um…that they should be familiar with?

P2 – Not really…I mean, you-you, there already is…a-a ya know, have the standard, um, technician, um for a regular airplane…a lot of the systems transfer over. I mean life support is more complex, but the basics are there.

Brent – Ok.

P2 – Ya know, a lot of the systems are more complex, but they're not…you already have them in place, you already have the-the control computers and stuff like that.

Brent – Ok. So similar to aircraft, but more complicated systems?

P2 – yes.

Brent – Ok. Um, moving on then number four: if you started with a clean slate, in your opinion, what are the most important subject areas an RLV technician must be familiar with?

P2 – Well from a clean slate…I mean…I think they need to, ya know, basically know what a standard airplane technician knows, plus um, ya know…know about rocket systems and how they work, and a basic understanding of that, and the chemicals and pressures involved with them.

Brent – Ok. The chemicals…is that a knowledge of chemistry? Or is that a knowledge of more applied, the specific chemicals?

P2 – More applied…the specific chemicals and how you handle them.

Brent – Ok, so clean slate you'd have somebody that maybe has their airframe and powerplant mechanic's license, that then additionally gets trained on the rocket systems and the chemicals and other things like that?

P2 – Yeah, I think that would be ideal because that gives them a pretty broad background, and then you're just adding the specialized components that you have in an RLV.

Brent – Ok, um, any other subject areas that you'd like to mention before I go on?

P2 – No…not really.

Brent – Ok, so this last one…I told you this would be painless, this is no big deal. This fifth question: with regards to RLV technicians, what have we not discussed that you feel is important?

P2 – Um…there's not anything that really comes to mind…I mean, ya know, there are…there will be areas on these vehicles that are highly specialized, and that the companies are just going to have to train them at. Um…but just, ya know, having a good background in the theory of…ya know, rockets and chemical handling, the kind of systems that you're gonna see on board will help a lot in training. Because all of these concepts are so radically different from each other, that, you know, just a good background so that they can come in and hit the ground running with the system…um, ya know, is probably going to be key in the short term.

Brent – Ok. So just, right now you're vision is more a general you know, maybe someone with airplane experience, that has some rocketry training, some chemical exposure or plumbing exposure, high pressure plumbing…

P2 – Mhm…

Brent – And then, comes to your company and learns you're specific subsystems?

P2 – Yeah, exactly…because I – I don't see how you could train the-the-the dozen or so concepts out there. And they're all very different. I just don't see how you could structure a program, um, that would, ya know…be able to be useful for everyone unless it's just a general knowledge and then they get the specific training when they get here.

Brent – Ok. Well that's fine. Is there anything else you'd like to mention that maybe you had in mind that I didn't ask you about, that you'd like to…get on the record?

P2 – No, not really, I mean, um…you know, a good source of training on how you do this stuff is over at the rocket propulsion labs at Purdue. Um, Scott Meyer has uh…you know, is really good at training people how to do, handle oxidizers and high pressure plumbing and stuff. Um, you might look at some of how he trains his students.

Brent – Ok…

P2 – It-it's basically what he does, um, year after year.

Brent – Ok.

P2 – So, um…just as kind of a source of information for you.

Brent – Ok.

P2 – But you've already talked to Scott already, right?

Brent – I have, yeah.

P2 – Yeah.

Brent – Ok, well if that's all, um, unless you have something else, I'll go ahead and shut down the recorder…

P2 – Nope.

Brent – Ok.

END RECORDED INTERVIEW

Date:	2/9/2010
Time:	11:30AM
Interviewer:	Brent Vlasman
Interviewee:	Participant 3 (P3)

Brent – Alright, the recorder is going. So this is the interview for the reusable launch vehicle maintenance project. Um, interview with Participant 3, and this is Brent Vlasman. And I'll go ahead and read you this opening statement and then we'll start with the questions. Um… Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle (RLV) technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, now that that's done, do you have questions before I get in to the actual interview questions?

P3 – Nope, I think I'm good.

Brent – Think you're good, ok. Question one: what do, and so you're kind of answering these on behalf, you know, of your company. Um…

P3 – Right.

Brent – What do or what did you look for in hiring your future or your current RLV technicians?

P3 – We look for all around engineering and problem solving skills. Um…in-in each case we look for engineers, um…that had, in the past, built their own something…hardware…from scratch. Um…we generally do not hire specifically aerospace engineering, uh…uh students or-or we go with an actual aerospace engineering degree, most of our employees are uh…mechanical engineers, electrical engineers…that sort of thing. Um…and what we're looking for is…people that understand how to solve problems cost effectively, fast, um…and do it on their own.

Brent – Ok. So…not necessarily a specific education, um…more experience based? Is that accurate to say?

P3 – Experience is a demonstration of a mindset…so it's a midset of somebody who…looks at an engineering problem, doesn't wait for somebody to come up with a solution for them, but goes and jumps right in, and-and takes a problem on their own, as creatively as possible. So the experience is certainly an indicator um…of a particular mindset that we're looking for.

Brent – Ok. Uh, that makes sense. Is there anything else you want to add to that?

P3 – Nah, I think that's good.

Brent – Ok. Second questions is: what additional knowledge areas would you like your technicians to possess?

P3 – Um…

Brent – If you need me to define anything or if the questions seem vague just let me know…

P3 – No…it's-it's an interesting question, I'm just trying to figure out if…well the thing that we're discovering is-is that, having a background in, uh…supersonic and hypersonic aerodynamics, and having a understand of basic propulsion issues…um, is an additional plus. All of our other systems…ah…and processes end up being fairly standard engineering…um…tasks. But, having an understand of-of-of hypersonic flight and basic rocket propulsion, um…is kind of a requirement for understanding the system.

Brent – Ok. Yeah, I was going to ask what you meant by propulsion? So you're looking primarily at rocket propulsion…is there anything specific that you'd like them to know about that?

P3 – Not really…as long as you understand some of the basic rocket equations and the basics of-of...um…you know, laminar fluid flow and things like that…that's sufficient. The rest of it can be learned.

Brent – And is that something…when you say learned…that you teach in house?

P3 – It's something you learn as you do. We don't necessarily teach it – we give you a task and we assume you can figure it out on your own.

Brent – Ok. Um…any other additional knowledge areas you'd like your technicians to know about?

P3 – Hm…project management.

Brent – Project management, really? Hm…ok. Um, question number three: what systems or subsystems should RLV technicians be familiar with?

P3 – Ah…again anything rocket propulsion. Control systems to a certain degree…especially anything dealing with the ah…flight control systems. But, ah…we have a-a-there's guidance, navigation, and control. Um, there's a branch of it that deals with some very heinous mathematics for integrating where you are and where you want to go and how you get there…um, we don't necessarily need everybody to know that, but having a familiarity with what it takes…and the-the assumptions that a system like that would- would require helps people understand the needs of the entire rocket system itself.

Brent – Ok, so…not so much on the equations for the guidance, um…in a control system…but more on the application? Is that accurate?

P3 – Right, understanding what it does to the system the things that perturb it, it's sensitivities and things like that, and-and it goes to…the guidance system is a black box if you want to think about it that way…this is a system of systems, um…approach, and you have to understand enough about the system that's in there to understand how they all react, or interact with each other.

Brent – Ok. Any other systems or subsystems they should be familiar with?

P3 – Ah…just going back to the previous question of-of basics about rocket propulsion.

Brent – Ok. Um…number four: if you started with a clean slate, in your opinion what are the most important subject areas an RLV technician must be familiar with?

P3 – Um…mechanical engineering in general. Um…accept for when you get into electrical engineering. Those two areas…if you get the basics of those, the rest of it can be taught and learned.

Brent – Ok. Then again you're talking about kind of learning through experience on the job there at Company ABC?

P3 – Right.

Brent – Ok. Is that the best way to teach them do you think?

P3 – We think- we think because one of the things we don't want is someone being taught how to solve these problems the standard NASA way, because that's too expensive.

Brent – Ok.

P3 – So...um…we get addition…we get value out of having…I don't want to say reinventing the wheel but…it's like for some of these things, the company can't teach you about them because we don't know about them either. We're trusting you as being a good engineer to go figure out the most creative, best, lowest cost solution, and to teach the rest of the company how to-how to-how to solve the problem.

Brent – Right…I guess I should have asked, I mean you mentioned the standard NASA way…is there kind of a baseline, uh…background that you're looking for in one of these technicians?

P3 – The base…eh seriously…the baseline that we look for is…are you a good engineer and have you built something. Not studied something – actually built something…whether it's a car or a rocket or a satellite or…ya know it doesn't really matter. We want to see that you're willing to pick up a welding torch, um…and-and-and figure out how to solve the problem with your hands.

Brent – So it's all about having build hardware in some capacity?

P3 – Yes.

Brent – Ok. Um…any other, for question number four there, any other subject areas…ya know, if money was no object for training?

P3 – Hypersonics.

Brent – Hypersonics are a big one for you?

P3 – Yeah.

Brent – Alright, and then this last question number five is kind of a catch all: with regards to RLV technicians, what have we not discussed that you feel is important?

P3 – Project management.

Brent – Ok, what do you mean by project management?

P3 – Having…understanding that your deliverables effect the company, and effects other deliverables and understanding where your tasks…understanding that…the process of building an RLV is just as much an engineering process as actually, you know, bending the metal and figuring out the-the-the problems. Um…A lot of engineers assume that somebody else is going to tell them when things are due…and, and that's not the case. We need engineers that understand, um…why due dates are what they are…understand what slippage means to the rest of the project.

Brent – Ok. That makes sense…if you uh…delay one step in that process then the whole thing can be delayed so you'd want them to be conscious of that.

P3 – Right, but if one of the things we find it's hard for them to understand is that…um…a delay is not strictly linear. That certain things, if they delay…cause other things to take even longer than were originally planned.

Brent – Hmm. Ok.

P3 – If-it's it's it's dependencies again. It's the same way that the vehicle is a system of systems…when you perturb any one of those things then all of your assumptions about how that system works fades.

Brent – Right. Ok, um that's all the scripted questions I have. If there's anything else you'd like to add…um…again the focus of this study is trying to get a picture of 'what is a reusable launch vehicle technician.' Um…and-and the way I'm going about it is asking some of these companies that are, you know…creating a vehicle…well what do you think it is? Because you're the subject experts…um…so is that pretty much the picture you'd like to paint?

P3 – Yeah, pretty much.

Brent – Um…creative, cost effective solutions…have experience on hardware…you'd like to see them have some rocket propulsion training…and some supersonic or hypersonic training…

P3 – Right, yeah, that's pretty much it.

Brent – That’s pretty much it. Ok, um…

P3 – And if you can find, if you can find somebody like that let me know…

Brent – Hahaha, ok…I’m going to go ahead and stop the recording then, unless there’s anything else you’d like to add on the record?

P3 – Nope, that’s it. And I’m just about at my stop, so I’m going to have to drop off. Is there anything else we need to do real quick?

Brent – Um, no that’s it. I’ll end the recording then…

END RECORDED INTERVIEW

Date:	2/16/2010
Time:	3:40PM
Interviewer:	Brent Vlasman
Interviewee:	Participant (P4)

Brent – Ok this is Brent Vlasman for the interview with the reusable launch vehicle maintenance technicians project. I'm interviewing P4, and I do have your permission to record this, correct?

P4 – Yes you do.

Brent – Ok. Well let me go ahead and read you the opening statement of the interview protocol, and then if you have any questions we can answer them, and if not we can start with the questions after that.

P4 – Alright.

Brent – So it's a couple phrases that I'm going to read you, so…here we go. Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle or RLV technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation's, Federal Aviation Administration's Office of

Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, that's the ah…opening statement. Um…

P4 – Yes sir.

Brent – Do you have any questions before we begin?

P4 – No, not in particular. Um, I might think of a few along the way, but I've got a pen and paper here, so…

Brent – Ok, and if you think of some along the way just let me know, um, there's no right or wrong answer, it's an exploratory study. And if something doesn't make sense I'll try and clarify…it's a pretty painless process.

P4 – Ok.

Brent – Ok, no further questions?...Question number one: what do or what did you look for in hiring your future or current technicians?

P4 – Um, with regards to our current technicians, which is…of which I am one, um, because our system was so um, sort of one of…it was not, uh, we-we actually developed the skills as we went.

Brent – Ok…

P4 – Um…that were, specific to the individual, ah, systems that we were working with. However, if I were looking to hire a technician, the things that I would be looking for with regard to the qualities of the technician would be…the uh…the ability to look at the overall path, and-and anticipate the needs along the way, and set up planning, ah…i.e. if there's a procurement of equipment, to see to it that that equipment can get you through…um, a few if not several iterations of your design process.

Brent – Is that what you meant by overall path, is the design process?

P4 – Yeah. The overall path being you know, ultimately you start from testing small vehicles with little hundred pound thrust engines. And sometime scale models. And then as you look towards scaling up, you know, when you look forward in-into the equipment needs and the logistical needs, that you as a- as an RLV technician are looking to implement the best possible processes and equipment…ah…that will-that will push you through several iterations. That way you're not looking at…'ok, this works good enough at this level…'

Brent – Ok.

P4 – Because then you- then you minimize the amount of redesign that you have to do in – with regard to support equipment.

Brent – Ok, that makes sense. Is there anything else you look for in technicians right now?

P4 - Um, right now with regard to technicians…um…

Brent – So if you were to hire somebody, what would you want, what would you want them to…

P4 – I would want them to have, ah…I would want them to have a wealth of experience in several different, uh, in several different areas. And the ability to think on their feet, and uh…and adapt. Adaptability is critical. Um, because sometimes one iteration might, er – one path that the vehicle is going down may end up being scrapped.

Brent – Ok.

P4 – And also I'd look for somebody that was capable of checking their pride at the door.

Brent – Hahaha, ok, checking pride at the door – got it.

P4 – Yeah.

Brent – Ok, moving on to question number two: what additional knowledge areas would you like your technicians to possess?

P4 – Um, the knowledge areas that I would like my technicians to possess would be basic construction skills. Um…because in a lot of basic construction you're dealing with similar things that you do in an RLV program. Basic construction skills being: a familiarity with wiring, electrical wiring, a familiarity with plumbing, and also, ah…certain structural, eh some structural familiarity to ah, enable to do some light-weight strengthening…i.e. if you need to add a certain amount of strengthening to, for example a reusable launch vehicle, that will support the load, you want it to be light weight. So light weight strengthening of structures, that sort of thing.

Brent – When you say construction do you mean, like residential, like building a house construction?

P4 – Residential, commercial…

Brent – Ok…

P4 – It’s amazing how often ah, that sort of thing comes into play. It’s-it’s-it’s-it’s not so much the – the actual skills themselves, it’s the thought processes that people that are experienced in those skills develop.

Brent – Interesting.

P4 – As they look at-at different structure…they, ah…the thought processes that is…are ‘where is the load going to go’ you know ‘what do I need to do to support that load?’

Brent – Huh, that’s interesting, I mean that makes sense when you describe the “subcharacteristics.”

P4 – Yeah, the subcharacteristic being, is being able to analyze, ‘ok, what does this need to make it stronger but not add a lot of weight?’

Brent – Ok…any other additional knowledge areas?

P4 – Well, uh the other additional knowledge areas one of the things that I’ve been a beneficiary of is for the last two years I’ve worked in cryogenics. Now, I would recommend that anybody who is ah…an RLV technician, be in the thought process of whatever type of propellant that they’re- they’re using.

Brent – Ok…

P4 – In our case – in our case it’s cryogenics and-and alcohol. Or cryogen plus another cryogen. For example oxygen and uh…liquid- liquid methane. So ah…a good familiarity with cryogenics, with handling of cryogenics, and also with the logistics of, ‘what is the plan, at the-at the point of launch, what is the plan? At-at the- at the point of launch, what is the plan? What do I need, what I as a technician need to make sure is there so that I can make sure that I have the appropriate tankage, the appropriate amount of materials on hand, and that we're not short, you know, we're not short any product. Especially if you're going to travel, for example we traveled about 700 miles to do launches. It took a considerable amount of advanced planning to make sure the product, that all of the propellants were there, and everything that we needed to support those operations.

Brent – Ok, so that kind of goes back to…

P4 – 700 miles from our home base…

Brent – Right, so planning is very important in that situation.

P4 – Oh absolutely. And you want somebody that –that can make a plan, follow through, but also be flexible. Flexibility is absolutely critical, especially in an experimentation process.

Brent – Ok.

P4 – And – and reusable launch vehicles are-are really really new. Ah, and I come from the perspective of, you know, small company type, ah…rather than, you know, the gigantic, you know, the –the giant monoliths of aerospace that have an office in, you know, ten different cities.

Brent – Right.

P4 – You know we have think like snails, or we have to think like military people. Military people have to bring with, you know, what, bring with them what they need to accomplish what they need to accomplish.

Brent – Ok. Um…getting into question three, um: what systems or subsystems should an RLV, should RLV technicians be familiar with?

P4 – Ah, the RLV technician, the primary thing that an R-RLV technician should be familiar with is, they should have an overall familiarity with how each of the subsystems interact to make the whole platform. Ah…it's-it's critical to know, for example, roll control thrusters. What are they, where are they, uh…whe-when…and part of it is kind of proofreading the system I like to, is what I like to call it – it's sort putting my eyeballs on each individual item and then trying to see, ok, have I even looked at it the right way. Do we have everything connected properly? Uh…the subsystems, ah…wiring harnesses, im-important to know how to build one. Ah, in case you run into the need for some quick in-field fabrication.

Brent – Ok.

P4 – Um…subsystems would be, ah…well really the loading platform for loading the vehicle. Also trying to minimize whatever in the loading process…for the vehicle itself…you want to minimize what's on the vehicle. If it has to made heavy, you know, try an-try and make it ground support equipment.

Brent – Ok, when you say "loading" what do you mean by that?

P4 – Uh filling the vehicle with propellant.

Brent – Ok so propellant loading.

P4 – Yeah. Which is my primary focus in-in the uh, operations that we conduct.

Brent – Ok. Um, so you mentioned wiring, um…some structure…what other, any other subsystems that you…you mentioned subsystems making the whole…are there any other specific subsystems that you'd like them to know about?

P4 – Well I think one of the, one of the um…the…let me think…um, as far as subsystems, ah…you want, you want to be familiar with ah, for example valve actuators and that sort of thing.

Brent – Ok.

P4 – Uh you want to be able to look at a valve actuator from the outside and know that it is on correctly and that your valves are positioned correctly.

Brent – So would you call…

P4 – Not always…

Brent – Go ahead…

P4 – I'm sorry go ahead…

Brent – I was saying would you call that hydraulics? Or is that a different system?

P4 – Well actually we're kind of getting into uh, question four.

Brent – Ok, sure alright here we go…transition, beautiful! If you started with a clean slate, in your opinion what are the most important subject areas an RLV technician must be familiar with?

P4 – The, I think the two most important, ah…systems that an RLV technician should be familiar with is electronics and plumbing. And one of the things I wish that I had a greater sense of…for my self, for my own knowledge, is electronics.

Brent – Ok.

P4 – Plumbing- plumbing is…rocketry is plumbing. Um…making a making a launch vehicle is essentially pluming.

Brent – Ok.

P4 – Ah, it's all of, it's all of the lovely electronic things that make it work beautifully.

Brent – Ok, what do you, what do you mean by electronics?

P4 – Um, for example, ah…for example in-internal to valve actuators would be valve positions sensors…ah…the ah, and knowing-knowing those systems very well that are, are inherent to your specific systems.

Brent – Ok.

P4 – Um…ah, the electronics with regard to ah…just being able to, you know, stick an ohmmeter on something and know what it's telling you.

Brent – Ok so some troubleshooting, maybe?

P4 – It's being able – being able to troubleshoot a problem that- if that- if a problem arises.

Brent – Ok.

P4 – Um but specifically, you know, being able to know where substance should be located, what to cleanup that sort of thing.

Brent – So if you were to summarize, I think you said it from the beginning, electronics and plumbing, those are your big ones?

P4 – Yeah, and an, an incredibly healthy dose of curiosity.

Brent – Ok.

P4- It-it takes a…one of the things you have to remember, that, you're not the smartest guy out there. You have to, we-we have the opportunity to stand on the shoulders of giants. With, you know, Von Bron and Goddard, and people like that, and it-you you want to make sure that when you, when you go out there you don't presume that you know everything.

Brent – Mhm.

P4 – Um…that's why you have to have a decent dose of curiosity. Um, that healthy dose of curiosity is particularly…uh, important, in building the whole system because then…if-if you understand how your, you know, for example, roll control thrusters react based on the center of gravity with a gimbleing system, you know, what is it going to do? Is it going to make the gimlbes want to shove a little bit in one direction, what is that going to do to the overall control of the vehicle?

Brent – Ok.

P4 – Um…aerodynamics would be a good healthy area to get some familiarity in.

Brent – Ok.

P4 – because, you you you know, as an RLV technician you want to look at, ‘ok, what are better aerodynamic shapes?’ But then at the same time, considering your design and what is your projected path further down the road, ok, do we want to be able to cart this, this…vehicle from place to place on a trailer and simply go over the road. Or are we going to have to air-ship it, are we going to have to, you know, get a super-guppy and to haul, you know, parts of it…parts of it around…

Brent – Right…

P4 – Um…and for, you know, for our purposes, our intent is to try and keep it under eight and a half feet. Because eight and a half feet is the limit of a, you know, of a vehicle’s width for going down the highway without a wide-load marker.

Brent – Right. That makes sense. You’re also involved with…it sounds like…design issues as well as maintainability issues.

P4 – Well maintainability, partly because our designs are ridiculously simple, ok…

Brent – Haha, ok…

P4 – Because if they were any more complex I think it would all go over my head.

Brent – Hm…ok…

P4 – Um…and then I would, then I would kind of get key-holed into that single slot of…um…you know, put the fill ports on this side of the vehicle so we can, so I know where to connect up hoses to or I know what connectors we need to put here.

Brent – Ok.

P4 – You know, that sort of thing. Um, the key is to, is to think of, think think long term…over…I mean, let me see if I can phrase this the best way possible.

Brent – Sure.

P4 – Making good decisions early helps you last longer term.

Brent – Ok.

P4 – Um…the, the, you have to be thinking of…what, you know, what is this the intended purpose of this vehicle. Are we going to lob some instruments up and simply do weather readings or something like that. You know, or, are we gonna try and put you in a reusable launch vehicle. Well then you run through a whole other system of how many redundant systems do we want with regard to safety. So you think of things like safety. Safety being the first, most critical thing.

Brent – Mhm.

P4 – Um…the-you-you know…you want to be able to transport it safely, you want to be able to fly it safely, you want to be able to bring it home safely.

Brent – Yeah, definitely. And that makes sense to have your, as much thought at the beginning of the design as possible so that your iterations are less…significant or less severe.

P4 – Well and that, the criticality of that is knowing the…back to the ability to look at the overall path.

Brent – Right.

P4 – You know, when you look at the overall path is what you're doing right now are these steps that are moving you down that path, or are you just sort of marching in place.

Brent – Right so it sounds like planning is high up there on the priority list of something that you want a technician to be conscious of.

P4 – Yes, absolutely. Ah, planning, planning is pretty critical. Ah, because uh…in a lot of case, in a lot of cases, for example in the larger aerospace firms you have people that do nothing but qualify wire. And for-for thirty years they'll qualify a crimp connection…on a launch system.

Brent – Ok.

P4 – The saddest part is that that launch system…that crimp connection that they've been qualifying for thirty years…when they fire that rocket, it's gonna go in the ocean.

Brent – Yeah.

P4 – And it's-it's never going to be reused. Well when you look at your system you want something that has simplicity of operation and reusability. Hence, the R in RLV…

Brent – Right.

P4 – Uh…but I think reusability is…simplicity is critical in making the reusability of the system.

Brent – Ok.

P4 – You want, you-you-you want simplicity so that you can verify that things are-are-are on there correctly.

Brent – Right.

P4 – And you-and you want overall familiarity with the vehicle.

Brent – Ok. Um, kind of a catch all question here at the end, this is the last question. With regards to RLV technicians, what have we discussed that you feel is important?

P4 – That was the biggest thing that I had a hard time answering. Because I did you look at your…at the document you sent Person ABC…um…

Brent – Well let me clarify…there's…

P4 – The biggest key…

Brent – Go ahead…

P4 – Oh I'm sorry go ahead…

Brent – No that's fine…

P4 – I think one of the, one of the larger keys is an open mind. And, and part of it is-is, part of that is, you know, checking your pride at the door, and having an open mind to not always being right.

Brent – Ok. And why is that important?

P4 – Um, I think that…I think that within the R, the reusable launch vehicle comminuty, there are…there are a lot of compromises made where people say ‘ok this was good enough to get us there’ and so that’s become sort of the rocket bible. Just because it was good enough to get there. Uh…if you keep an open mind, there could potentially be a much better, much simpler than just plain old good enough.

Brent – Ok. So it’s…

P4 – Um…

Brent – Or…maybe…receptiveness to new ways of doing things?

P4 – Yes, exactly.

Brent – Ok.

P4 – Um…there…for as much as, for example, things like metallurgy have changed in the last, you know, since we went to the moon, uh…there’s there’s some better manufacturing processes out there. They’re better-they’re better, better welding systems just for putting things together…

Brent – Right…

P4 – That have come into play. And-and so you have to, you try to take advantage of emerging-stuff that's emerging, proven technology.

Brent – Right.

P4 – That - that works well. Um…the loading panel on my…on-on my work station when we're doing uh…when we're doing our rocket operations looks like sort of like a-ah…you know, a German U-boat…from world war two…with it-with sort of a myriad of valves. But if you take a few moments to really look at it, look at the labels and what they say…I tried to make it simple enough, that anybody could step into that position, follow the checklist, and make the-and-and make the fill.

Brent – Ok. So, with this last question, and there's no right or wrong answer to it, an open mind is-is the big thing that we didn't talk about…like that I didn't specifically ask you about is having an open mind when you come in the door?

P4 – Yeah, having an open mind I think is-is pretty critical because you never know-you-you never know what is going to hit you, you know, some of the best ideas I get are in the shower in the morning.

Brent – Right…

P4 – And…being able to, to trus-to simplify that, and just, I mean, kee-keeping your mind open to, 'what could I, as a technician, be doing better, day in and day out, that would help the overall progress of the team?'

Brent – Ok. Um, I think that makes perfect sense. Is there anything else you want get, um, while I have the record going?

P4 – Um…can’t think of anything off the top of my head.

Brent – Ok.

P4 – Um…is there anything, are there any other questions that you might have?

Brent – No, that’s-that’s all I need for this study. If you don’t have anything else to add I’ll go ahead and stop the recording then.

P4 – Ok.

Brent – Ok.

END RECORDED INTERVIEW

Date:	2/16/2010
Time:	5:10PM
Interviewer:	Brent Vlasman
Interviewee:	Participant 5 (P5)

Brent – Ok, and this is Brent Vlasman interviewing P5 of company ABC, um for the reusable launch vehicle technicians project. Um, P5 I do have your permission to record this, is that correct?

P5 – That's correct.

Brent – Ok, um, what I'd like to do now is read through the opening statement. Um, in the document that I sent you, and then answer any questions you have before we start, and then we'll get into the interview questions.

P5 – Very good.

Brent – The opening statement goes as follows: Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle or RLV technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation's, Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, any questions before we get started with the interview?

P5 – No I'm good, thank you.

Brent – Good to go, ok question number one: what do or what did you look for in hiring your future or current technicians?

P5 – Well our current technicians are a conglomerate of people who originally started out as having the same mindset or the same passion to be able to develop our rocket vehicle technology on a volunteer basis.

Brent – Ok.

P5 – None of us were paid at the onset. We all wanted to create something special. And by special to us that meant something that would hop up and fly and be reusable so that we can conduct certain, uh, activities…with the hardware that were unique to reusability and-and fast turnaround.

Brent – Ok.

P5 – And as we kept those things in mind as we were going through all this, that the people that were involved had no previous training whatsoever in the specific field of aerospace.

Brent – Really?

P5 – They learned how to handle the chemicals, ah…by the basic standards that were already in place for industrial use.

Brent – Ok, so you took basically a volunteer crew and taught them…based on available materials?

P5 – Well…I have to include myself in that group even though I'm one of the principles at Company ABC right now I'm going to be in charge of training a lot of the people that come through here.

Brent – Ok.

P5 – Ah…at the time none of us had any training whatsoever so we were teaching ourselves as well as each other.

Brent – Interesting…ok, um, so…now looking towards the future what do you, or what would you ideally look for in hiring a technician?

P5 – If…someday there were a program, let's say there were a two year school that trains technicians like today you see electronics technicians and – and drafting technicians and you see technicians of different-different types in industry…if there were a two-year school that were to train technicians…the stroke of their training would be anywhere from documentation…to an understanding of what stored energy is, and how different types of stored energy can be…uh, dangerous so that a general idea of handling things that are, let's say, pressurized gases…that's a stored energy, which is, uh…potentially very dangerous…

Brent – Ok…

P5 – Uhh…and-and fittings and the disassembly and assembly of parts that may have already been in the field or what might go into the field and-and how…the details of-of-of-of those parts, in their operation…uh, pertain to different levels of safety either before or afterwards. For instance, uh, I-I grew up in the aviation industry as a lineman, and there were periodic times when I would be in the shop with the A and P mechanics…

Brent – Mhm…

P5 – And I remember them…there was probably five or six extremely expere-experienced, ah…aviation mechanics, disassembling this strut that they thought may have failed. With all the experience standing there watching what was going on, every single one of them overlooked the idea that the strut was still pressurized. And they couldn't figure out why one of the snap rings was stuck in so hard. So as one of the gentlemen was tapping the snap ring to pop it out, uh…nobody realized what was going to happen, or even imagined the possibility of their being any danger…and then not too far into the process as he was tapping the snap ring out it came loose and subsequently the inside of the strut came out rather…fast and hit a gentlemen in the chest.

Brent – Oooh.

P5 – That put him into a-a cardiac arrest type situation. Uh…where he survived it, but it didn't do him any good – he was really well bruised and of course the embarrassment of the rest of the gentlemen standing around not…going through a specific procedure with that particular part that they all knew better was what really, I found, interesting about that. Now…we can run into the same problems here when we're working on-on rocket technology.

Brent – Ok.

P5 – And it's typically not the really big dangerous operation of propellant loading or something like that that ends up being the hazard that hurts someone. It's simple little things that take you off your normal procedure that causes problems.

Brent – Hm.

P5 – For instance, during the ah…Lunar Lander challenge we landed the vehicle rotated a hundred and eighty degrees off from where it was intended to be because of a roll thruster problem. Well when we pulled the service vehicle up, we could not reach everything appropriately, so we had to go through a procedure, I mean we had to step off of the main procedure and try and go through this process still within our window of two and a half hours and-and-get things done within an appropriate amount of time. Well unfortunately we skipped a couple of steps on venting things down…and when we were beginning to load the propellants back into the vehicle and going into the actuator checks, when the actuator for the…pressurization system was activated…two things that ended up having 300 psi on the other side…uh, flailed wildly…and contacted two of our team members. It wasn't a life threatening situation…but it was certainly dangerous to say the least. And there are things like that that you would really want to be able to train your-your technicians to recognize because those are the types of situations that causes problems.

Brent – Ok.

P5 – Uh, obviously you want to train them in many other areas as well, but those are some of the key areas.

Brent – Ok, um…so kind of talking, and then getting more specific with this training, this question number two is a good transition: what additional knowledge areas would you like your technicians to posses? And you can include yourself in there if you'd like.

P5 – Ok. First of all, knowing and understanding what a procedure is and how to generate one based on what you're doing. How to, um…manage a procedure during the process, and keep a living document so that things can be added to and or taken away from as the uh…system evolves. And then in addition to that you want the person to understand stored energy, uh…capabilities, stored energy potentials such as pressurized gases. Um…chemical stored energy for instance if you're working with something like hydrogen peroxide, it has an inherent stored energy that's rather, ah…dangerous…ah, especially if there are contaminants involved it can go from just a benign liquid sitting in a container, to over pressurizing and exploding very very rapidly depending on, uh…contaminant content and cause serious problems. And then also you have cryogenics and then you have oxidizers mixed with fuel, so different types of stored energy there. So stored energy is key.

Brent – Ok.

P5 – And then you-you go over and look at the rocket systems themselves as mainly plumbing oriented. And then you also have electrical systems, but you want to be able to understand…ah, plumbing issues – how a valve works, how the-how the valve itself actually seals, what types of things you would see if the valve was failing and what types of failures you would see under certain conditions.

Brent – Ok.

P5 – Uh, and then just uh in general materials compatibility. That would be a very important part of it.

Brent – And by materials are you talking primarily structure of the vehicle? Or…

P5 – No.

Brent – No?

P5 – No, I' talking about materials that are in contact with oxidizers or fuels that may or may not be compatible with those oxidizers or fuels.

Brent – Ok…

P5 – For instance, some materials may be compatible with ethylene, but not with alcohol. Some materials may be compatible with-with the fuel, but not with the oxidizer.

Brent – Hm.

P5 – Some materials may be compatible at room temperature with peroxide but they won't be compatible with-with uh…lox. So there's a lot of differences there - in materials.

Brent – Ok, any other additional knowledge…I mean that's a great list, are there any other knowledge areas you'd like to include?

P5 – Let's see…I think I ran a pretty…a pretty large range.

Brent – Ok, and if you think of something, we can come back to it.

P5 – Alright.

Brent – I'll move on to the third question: what systems or subsystems should RLV technicians be familiar with?

P5 – For the most part, the RLV technicians are going to be…in direct contact with propellant loading and unloading, and then pressurization and depressurization. Those particular operations would involve being familiar with the, the plumbing system mainly, and then secondarily some of the electrical system and how those – those, different actuators work for valves and such, and then, uh…materials compatibility as well. So if you have a leak in a certain area, does that leak pose a problem to the flight or is it just an incidental problem.

Brent – Ok.

P5 – Ah…if you have a small oil drip under your engine, that wouldn't necessarily concern me. But if you had ahh-ahh an oil drip or an oil leak that was mixing with some form of liquid oxygen or other form of oxidizer in a rocket situation, that would be potentially very harmful, or dangerous. So you'd wanna know, know a lot about material compatibility, and then, and scenarios with the propellants, and with-with the plumbing itself.

Brent – Ok. So most of the compatibility you're talking about is the propellants or the chemicals interacting with each other?

P5 – Yeah, and then of course you want to have a good understanding of plumbing side of things as well because you…virtually every connection needs to have a, a vent…associated with it so that once propellant loading is terminated and the valves are closed you vent the connection before you, uh…open it. So there are, there's stored energy in there and sometimes in pressurized fluids if it's a cryogen and it's been boiling off in a trapped space you could potentially have a dangerous situation. Uh if the ball valves aren't vented appropriately, uh you could have a valve that closes and have, uh…liquid oxygen trapped in it and if it's not vented it could build pressure to the point where it explodes. And the same thing with peroxides and-and stuff like that. So…I mean it's really important to understand the nature of, of the material you're working with, and-and what types of requirements it has of the plumbing as well.

Brent – Ok. Um, that makes sense. Ok so here's kind of a-a bigger picture question number four: if you started with a clean slate, and maybe you are starting with a clean slate, in your opinion what are the most important subject areas an RLV technician must be familiar with?

P5 – Most important subject areas that they must be familiar with…RLVs are unique because you're dealing with propellants and you're also dealing with plumbing, and the plumbing you're dealing with generally is-is either going to be a very reactive material such as peroxide, or a cryogen such as liquid oxygen. So…you-you probably want to have some sort of industrial knowledge about the handling and function of different types of materials and handling equipment for those…those propellants. And then as it applies to the vehicle you'd wanna be able to maintain uh…a certain level of safety in-in the assembly and the-the loading. I don't know, perhaps I'm getting away from-from exactly what we need there but…

Brent – Oh no that's good. See the beauty of this, you know, study is that there is no…it's very exploratory, it's kind of…an uncharted territory and there's no wrong answer.

P5 – Right.

Brent – So, from what I'm hearing it's a lot of the plumbing side, um…material compatibility, and a knowledge of how to safely handle some of these uh…propellants? Would that be correct?

P5 – Right. Yes.

Brent – Ok. Um…if you started with a clean slate, any other subject knowledge areas that you'd like an RLV technician to be familiar with?

P5 – Well it…from an RLV technician perspective I can't think of anything right off the bat other than you know, they'd progress through just being a technician to being a crew chief to…whatever the case may be, but…

Brent – Ok.

P5 – Understanding the whole system in general is probably not going to be possible for every single one of the technicians on the job, so…uh…

Brent – Right…

P5 – It's just a matter of exposure. I-I-I don't know of any other way to-to put it.

Brent – Ok.

P5 – It-it, you know it…when I got out of tech school, originally, um…I wasn't like this super-smart wiz guy that would go out and change the world with my knowledge of electronics. Um…but I certainly had the-the tools I needed to progress through, uh…the requirements of my new position and being able to apply that to troubleshoot hardware and whatnot. So it's gonna be the same thing, they're-they're gonna need to have a-a basic understanding of plumbing – how it goes together what's good and what's bad and what kind of bad things can happen. Um…

Brent – Ok.

P5 – And just kinda…train from there.

Brent – Yeah, and I'm finding that a lot of these…roles, like you said, are very specialized and they'll have to do some on the job training to really understand the systems.

P5 – Well…yeah, I mean, uh…internships are great. Haha….when a student comes in and-and they're able to work with actual rocket hardware, and then they go back to their-their class and they say hey we did this that and the other thing and they ask their instructor why did we do this in particular, and he-he might have some knowledge that…answers the question there in his brain that wouldn't-wouldn't necessarily…just come out without the student the appropriate question.

Brent – Right. Ok. Um…number five is my catch all question here: with regards to RLV technicians, what have we not discussed that you feel is important?

P5 – Well when I was in the aviation industry I did take some training…um, that qualified me to be a what was called a lineman. And a lineman is basically an RLV technician except for aircraft.

Brent – Ok.

P5 – And we-we covered what was required for fueling the aircraft, either with av-aviation gasoline or with jet fuel. Uh, we also learned how to service the oxygen systems onboard, and what the sy-the basic safety requirements were for each of those. And these were-were training programs that were fairly extensive, it was probably…forty hours or so of classroom instruction and some practical stuff and then you had to take a test and…then you got this nice little certificate that you could put on your wall saying that you were a qualified lineman.

Brent – Ok.

P5 – Well I think the same things would apply to being qualified RLV technician. You'd wanna go through some formal training, exercise that would be…you know, ah a-reasonable, ah…bit of information that would have been accumulated over the years so far what we've done with-with our technology.

Brent – Ok.

P5 – Now whether or not we have enough information to make that happen effectively, uh…I think we're close. I don't know if we have an exhaustive set of information…Company ABC probably has a unique situation that we've worked with more different propellant types than virtually anybody in the world…uh, in any aerospace application.

Brent – Hm…

P5 – So this small team of X guys kind of knows their stuff when it comes a very wide variety of propellants.

Brent – That's pretty impressive. Ok, well…if there's anything else you'd like for me to capture on the record, um…is there anything else you'd like to get across, input with regards to an RLV technician in general?

P5 – Right off the bat, I-I'm I-m not thinking of anything except for possibly the regulatory side of things. There are…there are NFTA documents, ah, for instance if you're working on airport an FPA407 would be something you refer to uh…for propellant…handling or for fuel storage or for oxygen storage. Uh, but then there are other, uh…other NFTA documents that are specific to liquid oxygen, there are some that are specific to liquid methane, and then you've got DOT regulations so there might be some of these things that you get familiar with looking at the different, uh…ah…MSDS, and-and other safety protocols that are generally recognized out there if you're gonna, I mean through uh…NFTA. And-and knowing how to apply that information in an appropriate setting.

Brent – Ok and what is…

P5 – And what we…what we discovered is that even the guys at NASA…they-they handle things with kitten gloves to the point where they really don't understand what it is they're dealing with they treat it with such…an overwhelming respect, far beyond what the standard of industry is, that you would think they were handling, uh…nitroglycerine. Which you don't…uh, it-it is to be respected, but it can be taken overboard.

Brent – Right.

P5 – Uh, where-whereas if you…haha…see a liquid oxygen truck running down the road, it's something that you can park right next to…a school bus full of nuns and children on a fieldtrip, and be perfectly safe…haha.

Brent – Ok…

P5 – But when that, uh…same truck gets on site at a NASA facility, it cannot exceed five miles per hour, has an escort of two fire trucks, an ambulance, a header car and tailer car, I mean…the whole thing it –it –it gets kinda ridiculous when you see how they-they treat it.

Brent – Wow…

P5 – Whereas, you know, the standard side of the industry already has a very good grasp and an excellent safety record and…when it comes to handling these things it's um, it's uh…much less intense.

Brent – Ok, so…I think you-you said it well it's how to appro-appropriately apply those regulations or that knowledge to the RLV industry, is going to be important.

P5 – Sure.

Brent – Ok. Um…is there anything else you'd like me to capture on the record?

P5 – Uh…I can't think of anything right of the bat.

Brent – Ok, then I'm going to go ahead and stop the recorder now.

END RECORDED INTERVIEW

Appendix B. Coded Interview Transcripts

Date:	1/29/2010
Time:	4:05PM
Interviewer:	Brent Vlasman
Interviewee:	Participant 1 (P1)

Brent - OK this is Brent Vlasman interviewing P1 for the reusable launch vehicle technicians project. I'm going to go ahead and read the opening statement…and I just want to have on record P1, that I do have your permission to record this?

P1 – Yes, you do have my permission, my name is P1 and I'm with Company ABC.

Brent – OK thanks. I'll read this, and then we can start with the questions…

P1 – OK.

Brent – Um, Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle (RLV) technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, do you have questions before the first question?

P1 – Nope!

Brent – Nope, ok, so question one: What do or what did you look for in hiring your future or your current technicians?

P1 – Ok, this applies both to past, present, and future.

Brent – Ok.

P1 – The first thing we look for is attitude **[attitude]**.

Brent – Ok.

P1 – Umm…the type of attitude **[attitude]** that a person has, uh, the RLV companies, Company ABC is one, Company ABC is another, Company ABC, Company ABC…we're breaking new ground **[new ground]** and we need people who are willing to break new ground. In other words, we have interviewed people who have been in one industry for 10-15-20 years and their, ah, attitudes **[attitude]** are set towards a certain way and if you say, 'well let's try it a little bit different way' **[new ground]** they will balk.

Brent – Hmm.

P1 – So, ah…frankly what we look for is people who have ah, an attitude **[attitude]** that is, 'Ok, I've got some experience in something else, let's try it **[flexibility]**.' For instance, the gentleman who is our chief engineer started out designing submarines **[experience diversity]**. The gentleman who is in charge of our shop was the top diesel mechanic **[mechanical aptitude]** at a truck stop **[experience diversity]**.

Brent – Hmm.

P1 – So…we look for…not aerospace experience per se, or even airplane experience per se **[experience diversity]**, but an attitude **[attitude]** that wants to do this **[enthusiasm]**.

Brent – Ok.

P1 – That's the first thing we look for. The next thing we look for is experience. Ah…and even in interns, and we do take college interns…we encourage college interns. We want to look for people who have had experience in life **[experience diversity]**…say our senior engineer grew up in a machine shop **[machine shop]**, his dad owned a racing comp…ahh…group, so he grew up with racing cars **[racing experience]** …

Brent – Ok…

P1 – Therefore he understands both high performance **[high performance]** mechanics and…he gained a personal eye to the dangerous or…difficult situation **[safety critical]**. Does -does that help you at all?

Brent – Yeah, no this is good – the only reason I'm not talking I'm taking some notes while we're going through this…

P1 – Sure, sure.

Brent – Ok, so you look for attitude, and maybe some flexibility in there…right now I'm just kinda paraphrasing you, correct me if I'm wrong.

P1 – Sure, uh huh…

Brent – And in the experience is there…um…uh, hands on type experience?

P1 – Yeah…

Brent – You said machine shop and racing and stuff like that?

P1 – Yeah, we look for hands on experience **[hands-on experience]**. Someone who has, uh, sat at a computer, or who is…what we like to call a-a-a 'me too-er', in other words 'hey that's a good idea', 'yeah me too I think that's a good idea' is-is…they just, they're nice people…but they just don't have the experience we need. For instance, if we need something welded **[welding]**, I'm out in the welding shop. Uhh…if we need the bathroom cleaned sometimes the president of the company goes and cleans the bathroom…uh…you have to flexible **[flexibility]**, you have to understand you need to do different things **[attitude]** **[experience diversity]**.

Brent – Mhm.

P1 – Uhh…in order to get the job done.

Brent – Ok. Do you have anything else that you look for in – in hiring your technicians?

P1 – Hmm…let's see…attitude **[attitude]**, experience **[experience]**, ability, oh…a knowledge of your own limitations **[self awareness]**.

Brent – Ok…

P1 – That's very important. Uhh…it…if someone doesn't understand that they don't understand something **[self awareness]**, they can kill people **[safety critical]**.

Brent – Ok.

P1 – And…we don't to have…and we have had to…uh…let people go who didn't understand their own limitations **[self awareness]**.

Brent – Ok. I think that's a good segue into the second question, it's knowing your limitations so what additional knowledge areas would you like your technicians to possess?

P1 – Oooh…I don't want to pin anything down because we have…we found that, ya know, somebody who…uh…worked on a really weird, uh, pump 25 years ago, that has turned suddenly relevant to what we are doing **[experience diversity]**. Uh we have a guy who uh…we had a guy…our chief machinist **[machine shop]** as a matter of fact…works on steam locomotives **[experience diversity]**…

Brent – Hmm...

P1 – And his experience is directly relevant to some of the rocket engine parts that we make **[fabrication]**.

Brent – Really?

P1 – So…additional knowledge…I-I can't specify.

Brent – Ok, that's fine…ya know…

P1 – Yeah…

Brent – Any answer is ok…there's no right or wrong here…

P1 – No I understand that, it's just…thinking about it…you always like um, people to have say…the knowledge of certain computer programs like CATIA, or…MATLAB…or SolidWorks **[CAD]**…that's real helpful…

Brent – Mhm…

P1 – Um…I hadn't even thought about the electronics side of it…cause we're…since we're about half electronics **[electronics]** and half mechanics **[mechanical]**. In other words – we'll design something on a computer [**CAD]** and then we'll go building it **[fabrication]**.

Brent – Ok.

P1 – Yeah, a-a-a good computer grounding **[CAD]** obviously is-is important.

Brent – Ok. Anything else for that?

P1 – Huh uh.

Brent – Ok, it sounds like it's kind of a broad skill set and that's kinda hard to pin down, you know…

P1 – It is! It is….well especially because we're…we're breaking new ground **[new ground]**. Uh…ya know with an established, mature industry like the airline industry they can name exactly what they need…

Brent – And they do…

P1 – We're not…yeah, and we're not there yet. Ya know, we're still not floundering, but you know, we're still chopping the weeds **[new ground]**…

Brent – Ok. Um, I'll move on to question three then…

P1 – Uh huh.

Brent – What systems or subsystems should RLV technicians be familiar with?

P1 – Ok now, are you talking about hiring a new person? Or someone who…after he's hired?

Brent – It could be either…I'm really looking for the total knowledge base of an RLV technician.

P1 – Ok, well…I-un-unfortunately which RLV are you talking about **[RLV diversity]**? Haha…

Brent – Haha…well…yours I guess…

P1 – Ok…haha…let's specify ours because just as there are semi-trailer trucks as well as two seater sports cars **[RLV diversity]**…

Brent – Mhm…

P1 – You're gonna have the same, ah…diversity in-in launch vehicles **[RLV diversity]**.

Brent – Right…

P1 – So, ours looks like an airplane **[airplane-like]**. We can’t call it an airplane, but it looks like an airplane. So what I need is someone who understands the aerodynamics **[aerodynamics]** of both subsonic **[subsonic aerodynamics]** and supersonic **[supersonic aerodynamics]**.

Brent – Ok.

P1 – Ah…someone who understands ah, composites **[composite materials]**.

Brent – K.

P1 – And- and how to work with them. Uh…geeesh…there are going to be folks like, just like A and P’s **[A&P similarity]**, there are gonna be folks who specialize more on the engines **[propulsion specialist]** side, than the airframe **[airframe specialist]** side.

Brent – Ok…so maybe an engine or propulsion specialist?

P1 – Yeah, propulsion specialist **[propulsion specialist]** and again we’re gonna have to train them from scratch **[internal training]**…

Brent – Right…

P1 – Pretty much…our engines are different from Company ABC’s engines are different from Company ABC’s are different from Company ABC’s **[RLV diversity]**…so…

Brent – And that’s why you have to train them from scratch?

P1 – Just about. Also, I don’t think it’s like learning airplane engines in 1900.

Brent – Mhm.

P1 – There weren't any…ok?

Brent – Mhm.

P1 – They were struggling to get some…it wasn't until you had a half-way decent-decent engine that you could get heavier than air flight. Um, and there were a lot of different engines and there were a lot of different technicians working on them. Uhh…what did Manly work like what five years on that engine that Langley used? And the point-the point is that…um…the technicians have to have strong mechanical skills **[mechanical skills]** no matter what.

Brent – Ok.

P1 – And then we'll get specific from there **[internal training]**.

Brent – Ok. Um, so…a-a general mechanical aptitude…

P1 – Yeah...

Brent – Is what you're looking for?

P1 – Yeah, yeah. And if they've had some physics **[physics]** and chemistry **[chemistry]** so that they know not to mix, you know, tryiline and hydrazine together, that'd be nice…but since we don't use those chemicals anyways ok, but a-a-a-basic understanding of chemistry **[chemistry]** is really good. And you need for that life anyways so…

Brent – And is that something that you train your people on…or you would…is the basics of chemistry? Or do you kind of…

P1 – Oh yeah…we not only train them on that **[internal training] [chemistry]**, we train them how to write **[internal training] [written communication skills]**. We train them English **[communication skills]**…

Brent – Ok.

P1 – Uh…that's another…back up to number, ah, number two…

Brent – Mhm.

P1 – I-I should have mentioned this…is we need very strong, good English skills **[communication skills]**.

Brent – Hmm. Ok.

P1 – Well…a misplaced comma can kill somebody **[communication skills] [safety critical] [attention to detail]**.

Brent – No, that makes sense…

P1 – Yeah, so…we-we need good English **[communication skills]** and good writing **[written communication skills]**…

Brent – Good English and communication?...

P1 – Uh huh.

Brent – Ok…um…anything else for systems and subsystems that you can think of?

P1 – Mm….not right off.

Brent – Ok. Question number four:

P1 – Uh huh.

Brent – If you started with a clean slate, in your opinion what are the most important subject areas for an RLV technician to be familiar with?

P1 – Ok, chemistry **[chemistry]**.

Brent – Chemistry.

P1 – Physics **[physics]**.

Brent – Ok.

P1 – Uhh, basic engineering **[engineering]**.

Brent – What do you mean by basic engineering?

P1 – Well…uh…understanding umm, that uh…different fasteners are needed for different applications **[applied engineering]**. In other words, uh…you don't use a bolt where a rivet will do…

Brent – Ok.

P1 – Umm…you, I mean…stuff you get in engineering 101 **[basic engineering]**…

Brent – Ok, so you have…loads, and statics dynamics…

P1 – Yeah…

Brent – That type of thing…

P1 – A little bit yeah….and some, practical stuff **[applied engineering]**.

Brent – Ok…

P1 – Let's see…a little bit of avionics **[avionics]** would be helpful.

Brent – Ok, and is that aviation-like avionics, or is this?...

P1 – Yeah, yeah-yeah…

Brent – Ok.

P1 – Aviation **[aviation-like] [avionics]**. Yeah we try to…everybody who's here we encourage to fly **[piloting]**…

Brent – Ok…

P1 – And we have, uh…private pilots here **[piloting]**, and people who own their own airplanes and it's not that we're airplane fanatics, but the more you fly **[piloting]** the more you understand regime that you're working in **[experience diversity]**.

Brent – Right, that makes sense.

P1 – Yeah so pilot's license would be nice **[piloting]**.

Brent – Ok.

P1 – One of the things Company ABC does which is really great, is they require their engineers to have built an airplane **[homebuilding experience]**.

Brent – Hmm.

P1 – And we don't require that, but um…if somebody says 'hey I'm working on an airplane' or 'I designed and built model airplanes and flew em' or 'hey I designed and built a submarine' that would be good **[homebuilding experience]**. That-that's really highly desirable.

Brent – Ok, so you look for homebuilding experience of some sort?

P1 – Yeah – yeah even if it's a racecar **[racing]**, or models, or whatever **[experience diversity]**…homebuilding is-is…

Brent – Ok.

P1 – Desirable, yeah **[homebuilding]**.

Brent – Ok…so…just looking at my notes…chemistry, physics, and the basics of engineering…avionics and then some homebuilding or flight experience…

P1- Yeah…

Brent – Anything else that you'd like, um, subject wise, them to be familiar with? Again…this is in the ideal world…money is no issue…

P1 – Yeah…hahahaha…well they oughtta get all the movie references – Buckaroo, Bonzai, Star-Wars, that kinda thing…but uh….

Brent – Movie references…ok…hahaha…

P1 – Hahaha…well we take our job very seriously, but we don't take ourselves seriously **[attitude]**, and we like to joke around…

Brent – Ok…

P1 – And you know, somebody picks up…a finger protecter and goes 'exterminate! Exterminate!'…everyone gets the reference…so…

Brent – Right…haha ok so…I gotta have movie training on there…haha

P1 – Yeah…hahahaha.

Brent – Ok, is that all that you can think of for…ah…subject areas?

P1 – Yeah…

Brent – Ok. And if there's anything…ok so here's kinda the catch all question number five…

P1 – Uh huh…

Brent – With regards to reusable launch vehicle technicians, what have we not discussed that you feel is important?

P1 – Hmm…They're going to have to have a toleration of government intervention **[regulatory interaction]**.

Brent – Ok. What do you mean by that?

P1 – Alright…hey you're an A and P, right?

Brent – Correct.

P1 – Ok…they FAA can be a real pain in the neck.

Brent – Ok.

P1 – And occasionally…I know even dealing with them when I get my medical…whose neck to I wring, ok **[regulatory interaction]**? I'd love to be Darth Vader ever once in a while 'I find you're lack of faith disturbing'…

Brent – Hahaha…

P1 – But ahh…haha..it would get things done…because ah, once again, RLVs are breaking new ground **[new ground]**, we have to train the regulators **[regulatory interaction]**.

Brent – Ok.

P1 – In what we're doing…and explain to them that what we're doing is not going to cause the demise of western civilization as they know it **[new ground]**.

Brent – Ok.

P1 – Which they occasionally think we are. So you have to have…a certain degree of tolerance of explaining things to them and **[regulatory interaction] [communication skills]** – and realizing they're really trying to help, they just don't want you to have a bad accident when they're in charge.

Brent – Right, ok.

P1 – So, uh…a certain amount of being able to sit back and realize and explain **[communication skills]** to ignorant but interested people **[regulatory interaction]** what you're doing is helpful.

Brent – Ok, so some patience for dealing with…

P1 – Patience…

Brent – With the regulatory agencies?

P1 – Yeah…yeah.

Brent – Ok. Anything else that you'd like to mention that I didn't necessarily ask you specifically?

P1 – Ohh….I'm trying to think…um…once again, I'd like to emphasize that all these launch vehicles are different **[RLV diversity]**.

Brent – Ok.

P1 – So what's good for one is not necessarily going to be helpful for somebody else **[RLV diversity]**.

Brent – Right.

P1 – Um…ya know, if-if a top engine from say, Roushce or one of the other uh…racing **[racing]** car companies came to me and said I want to work for you I'd hire him in two seconds.

Brent – Why is that?

P1 – Or if…because he's got a tremendous amount of experience dealing with harsh environment **[high performance]**, for the-the mechanics **[mechanical]** of what they're doing…

Brent – Mhm.

P1 –Umm…uhh…doing new and different things **[new ground]**, and making sure that the people who are using these new and different things are going to be ok **[safety critical]**, that they're going to be safe….

Brent – Ok…so it sounds like, and I don't wanna put words in your mouth, so don't let me…um.. it's kind of an attitude of flexibility and safety consciousness, moreso than…ya know, 'thou shalt have this many hours of this experience on this…'

P1 – Correct…yes-yes that is correct. When we hire people, we don't necessarily look at their grades, and we don't necessarily look at their degree **[experience diversity]**. We hired a-a-business major once as a junior engineer and it worked out really well. And he became a really good engineer, lousy business major but a really good engineer…haha. Ah-again it was his…it was his enthusiasm **[enthusiasm]** and his attitude **[attitude]** as well as his mind…

Brent – Mhm.

P1 – Um…and ah he…he went ahead and got his business degree and then became an engineer and I think he's working for Company ABC now…he's one of their junior engineers over there now.

Brent – Ok. So with your technicians you're less focused necessarily on technical competency, more on the…attitude and-and character of the person?

P1- Yeah…

Brent – At least right now…

P1 – Yeah, character **[character]** is real important.

Brent – Ok.

P1 – Once again, if you lie [**honesty]** you're gonna kill people **[safety critical]**. So…

Brent – Yeah…

P1 – We have to make sure that our people are…trustworthy **[trust]**, honest [**honesty]**, brave, thrifty, whatever else it is that the scout's motto is…hahaha…

Brent – Hahah…is there anything else that you'd like to add that I haven't got to ask you yet?

P1 – No…I think, think we've pretty much done it here…if you're happy?

Brent – Oh I'm happy…um…

P1 – Ok.

Brent – Then I'm gonna go ahead and end this recording. This ends the interview with P1 of Company ABC, and it is what…January 29th, of 2010.

P1 – Yep.

END RECORDED INTERVIEW

Date:	2/3/2010
Time:	3:45PM
Interviewer:	Brent Vlasman
Interviewee:	Participant 2 (P2)

Brent – Ok the recorder is going. Um this is Brent Vlasman, this is the interview with Participant 2 for the reusable launch vehicle maintenance project. And I do have your permission to record this, Participant 2?

P2 – Yes, you do.

Brent – Ok, then I will go ahead and get into the interview protocol, read this opening statement, and then we'll start with the questions. So the opening statement is: Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle or "RLV" technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation, um Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, do you have questions before I get in to the actual interview questions?

P2 – Nope.

Brent – Nope, ok. And if you do, I mean, you can just ask along the way and I will clarify if something is unclear.

P2 – Ok.

Brent – Ok, so question number one: what do or what did you look for in hiring your future or current technicians?

P2 – Um, well generally just a-a broad knowledge base **[broad knowledge base]**. Um, the more they can do the better **[versatility]**. Um, ya know, we typically have to…the the the one thing that ah, you know, that will be significantly different in these systems that will, like current airplanes **[airplane-like]** and such, is a large amount of oxidizers **[oxidizers]** are stored on these vehicles. Um, so familiarity with handling **[oxidizer handling]** of oxidizers **[oxidizers]** is a big plus…

Brent – Ok.

P2 – And if you can find someone who's trained.

Brent – Ok, and when you said the more they can do the better what types of things did you mean?

P2 – Hmm, um, well a technician is plumbing **[plumbing]** and electrical **[electrical]** and troubleshoot **[troubleshooting]**, and you know, you basically you can point them at a problem, and have them fix it and know that they're, ya know, qualified to fix it **[confidence in abilities]**, ya know, that's great…especially in R and D programs, they can do a little bit of everything **[versatility]**…from electrical **[electrical]** to plumbing **[plumbing]**, um, to torqueing bolts and that kind of thing.

Brent – Ok.

P2 – But, ya know, specifics…we have to…the systems are going to be specialized **[specialized systems]**, and there will have to be specialized training **[specialized training]** for each vehicle **[RLV diversity]**.

Brent – Ok.

P2 – But the general broad knowledge base is about the best **[broad knowledge base]**.

Brent – Ok, um…what additional, so this is the second question, what additional knowledge areas would you like your technicians to possess?

P2 – Oxidizer **[oxidizers]** handling **[oxidizer handling]** and safety **[safety]** is one of the biggest ones that we spend a lot of time **[time consuming]** having to train them **[internal training]**. If they came in already trained on oxidizers **oxidizers]**, um, that would save a significant amount of time **[time consuming]**.

Brent – Ok, is that something that you do internally, or is there some place that you…subcontract that training? Or…

P2 – We do that internal **[internal training]**, um…so that we can…there's places you can contract out, um…NASA has a training program, um, on oxidizers **[oxidizers]**…um, and I think even out of, um…the…I can remember which base it is in New Mexico…but I'm pretty sure that they're the ones with the oxidizer training **[oxidizers]** and handling **[oxidizer handling]** course…um…

Brent – Ok, so knowledge of oxidizers and handling them?

P2 – Mhm.

Brent – Is there anything else?

P2 – Not really, I mean a lot of the systems just aren't that different from, ya know, a traditional plane **[airplane-like]**.

Brent – Ok.

P2 – Um…for the basic knowledge skill set **[broad knowledge base]**.

Brent – So are you assuming…

P2 – I mean how…

Brent – Oh I'm sorry, go ahead…

P2 – How everything is implemented is different **[RLV diversity]**, but you know, a lot of what's there, ya know the landing gear doesn't change if you've got wheels, you know…things like that don't change **[airplane-like]**…

Brent – Right…

P2 – It's just that you-you're dealing, the biggest thing is you're dealing with different chemicals **[chemicals] [oxidizers]** on board…

Brent – Right, and so are you, kind of coming at it as if the person has a baseline in aviation maintenance?

P2 – Yeah, if they do **[airplane-like] [A&P similarity]**…

Brent – Ok.

P2 – Ya know, adding in oxi-oxidizer **[oxidizers] [oxidizer handling]** training and the other thing is high pressure systems **[high pressure systems]**.

Brent – Ok, high pressure systems.

P2 – If they know high pressure **[high pressure systems]** plumbing **[plumbing]**, and you know, if they're comfortable working around, you know, several thousand PSI **[high pressure systems]** that's a big plus too.

Brent – Ok. What systems or subsystems should RLV technicians be familiar with?

P2 – Well, a basic understanding of – of rocketry **[rocketry]** and jet engines **[gas turbines]** is, ya know, key. They don't have to be able to design one, but they need to know the basic components **[component knowledge]** and the parts. Um, you know, just as they would for someone who works on a piston driven engine **[airplane-like] [A&P similarity]**.

Brent – Ok. Um, any other systems or subsystems…um…that they should be familiar with?

P2 – Not really…I mean, you-you, there already is…a-a ya know, have the standard, um, technician **[A&P similarity]**, um for a regular airplane **[airplane-like]**…a lot of the systems transfer over. I mean life support is more complex **[increased complexity]**, but the basics are there **[airplane-like]**.

Brent – Ok.

P2 – Ya know, a lot of the systems are more complex **[increased complexity]**, but they're not…you already have them in place **[airplane-like]**, you already have the-the control computers **[electronics] [avionics]** and stuff like that.

Brent – Ok. So similar to aircraft, but more complicated systems?

P2 – yes.

Brent – Ok. Um, moving on then number four: if you started with a clean slate, in your opinion, what are the most important subject areas an RLV technician must be familiar with?

P2 – Well from a clean slate…I mean…I think they need to, ya know, basically know what a standard airplane technician knows [**A&P similarity]**, plus um, ya know…know about rocket systems **[rocketry]** and how they work, and a basic understanding of that **[broad knowledge base]**, and the chemicals **[chemicals] [oxidizers] [oxidizer handling]** and pressures **[high pressure systems]** involved with them.

Brent – Ok. The chemicals…is that a knowledge of chemistry? Or is that a knowledge of more applied, the specific chemicals?

P2 – More applied…the specific chemicals **[chemicals] [oxidizers]** and how you handle them **[oxidizer handling]**.

Brent – Ok, so clean slate you'd have somebody that maybe has their airframe and powerplant mechanic's license, that then additionally gets trained on the rocket systems and the chemicals and other things like that?

P2 – Yeah, I think that would be ideal because that gives them a pretty broad background **[broad knowledge base] [A&P similarity]**, and then you're just adding the specialized **[specialized systems]** components that you have in an RLV.

Brent – Ok, um, any other subject areas that you'd like to mention before I go on?

P2 – No…not really.

Brent – Ok, so this last one…I told you this would be painless, this is no big deal. This fifth question: with regards to RLV technicians, what have we not discussed that you feel is important?

P2 – Um…there's not anything that really comes to mind…I mean, ya know, there are…there will be areas on these vehicles that are highly specialized **[specialized systems]**, and that the companies are just going to have to train them at **[internal training]**. Um…but just, ya know, having a good background **[broad knowledge base]** in the theory of…ya know, rockets **[rocketry]** and chemical **[oxidizers] [chemicals]** handling **[oxidizer handling]**, the kind of systems that you're gonna see on board will help a lot in training. Because all of these concepts are so radically different from each other **[RLV diversity]**, that, you know, just a good background **[broad knowledge base]** so that they can come in and hit the ground running **[internal training]** with the system…um, ya know, is probably going to be key in the short term.

Brent – Ok. So just, right now you're vision is more a general you know, maybe someone with airplane experience, that has some rocketry training, some chemical exposure or plumbing exposure, high pressure plumbing…

P2 – Mhm…

Brent – And then, comes to your company and learns you're specific subsystems?

P2 – Yeah, exactly…because I – I don't see how you could train the-the-the dozen or so concepts out there **[RLV diversity]**. And they're all very different **[RLV diversity]**. I just don't see how you could structure a program, um, that would, ya know…be able to be useful for everyone unless it's just a general knowledge **[broad knowledge base]** and then they get the specific training **[internal training]** when they get here.

Brent – Ok. Well that's fine. Is there anything else you'd like to mention that maybe you had in mind that I didn't ask you about, that you'd like to…get on the record?

P2 – No, not really, I mean, um…you know, a good source of training on how you do this stuff is over at the rocket propulsion labs at Purdue. Um, Scott Meyer has uh…you know, is really good at training people how to do, handle oxidizers **[oxidizers] [oxidizer handling]** and high pressure **[high pressure systems]** plumbing **[plumbing]** and stuff. Um, you might look at some of how he trains his students.

Brent – Ok…

P2 – It-it's basically what he does, um, year after year.

Brent – Ok.

P2 – So, um…just as kind of a source of information for you.

Brent – Ok.

P2 – But you've already talked to Scott already, right?

Brent – I have, yeah.

P2 – Yeah.

Brent – Ok, well if that's all, um, unless you have something else, I'll go ahead and shut down the recorder…

P2 – Nope.

Brent – Ok.

END RECORDED INTERVIEW

Date:	2/9/2010
Time:	11:30AM
Interviewer:	Brent Vlasman
Interviewee:	Participant 3 (P3)

Brent – Alright, the recorder is going. So this is the interview for the reusable launch vehicle maintenance project. Um, interview with Participant 3, and this is Brent Vlasman. And I'll go ahead and read you this opening statement and then we'll start with the questions. Um… Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle (RLV) technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, now that that's done, do you have questions before I get in to the actual interview questions?

P3 – Nope, I think I'm good.

Brent – Think you're good, ok. Question one: what do, and so you're kind of answering these on behalf, you know, of your company. Um…

P3 – Right.

Brent – What do or what did you look for in hiring your future or your current RLV technicians?

P3 – We look for all around engineering **[basic engineering]** and problem solving **[problem solving]** skills. Um…in-in each case we look for engineers, um…that had, in the past, built their own something **[homebuilding]**…hardware…from scratch [**fabrication] [hand-on experience]**. Um…we generally do not hire specifically aerospace engineering, uh…uh students or-or we go with an actual aerospace engineering degree, most of our employees are uh…mechanical engineers **[mechanical engineering]**, electrical engineers **[electrical engineering]**…that sort of thing. Um…and what we're looking for is…people that understand how to solve problems **[problem solving]** cost effectively **[budget-minded]**, fast **[fast-paced]**, um…and do it on their own **[independent] [self-motivated]**.

Brent – Ok. So…not necessarily a specific education, um…more experience based? Is that accurate to say?

P3 – Experience is a demonstration of a mindset **[attitude] [character]**…so it's a mindset of somebody who…looks at an engineering problem, doesn't wait **[fast-paced]** for somebody to come up with a solution for them **[independent] [self-motivated]**, but goes and jumps right in **[enthusiastic]**, and-and takes a problem on their own **[independent]**, as creatively **[creativity]** as possible. So the experience is certainly an indicator um…of a particular mindset **[attitude] [character]** that we're looking for.

Brent – Ok. Uh, that makes sense. Is there anything else you want to add to that?

P3 – Nah, I think that's good.

Brent – Ok. Second questions is: what additional knowledge areas would you like your technicians to possess?

P3 – Um…

Brent – If you need me to define anything or if the questions seem vague just let me know…

P3 – No…it's-it's an interesting question, I'm just trying to figure out if…well the thing that we're discovering is-is that, having a background in, uh…supersonic and hypersonic aerodynamics **[aerodynamics] [supersonic aerodynamics] [hypersonic aerodynamics]**, and having a understand of basic propulsion **[rocket propulsion]** issues…um, is an additional plus. All of our other systems…ah…and processes **[engineering processes]** end up being fairly standard engineering **[basic engineering]**…um…tasks. But, having an understand of-of-of hypersonic flight **[aerodynamics] [hypersonic aerodynamics]** and basic rocket propulsion **[rocket propulsion]**, um…is kind of a requirement for understanding the system **[system understanding]**.

Brent – Ok. Yeah, I was going to ask what you meant by propulsion? So you're looking primarily at rocket propulsion…is there anything specific that you'd like them to know about that?

P3 – Not really…as long as you understand some of the basic rocket **[rocket propulsion]** equations **[basic engineering]** and the basics of-of...um…you know, laminar fluid flow and things like that…that's sufficient. The rest of it can be learned **[learning on-the-job]**.

Brent – And is that something…when you say learned…that you teach in house?

P3 – It's something you learn as you do **[learning on-the-job]**. We don't necessarily teach it – we give you a task and we assume you can figure it out **[problem solving]** on your own **[independent] [self-motivated]**.

Brent – Ok. Um…any other additional knowledge areas you'd like your technicians to know about?

P3 – Hm…project management **[project management]**.

Brent – Project management, really? Hm…ok. Um, question number three: what systems or subsystems should RLV technicians be familiar with?

P3 – Ah…again anything rocket propulsion **[rocket propulsion]**. Control systems **[control systems]** to a certain degree…especially anything dealing with the ah…flight control systems **[flight control systems]**. But, ah…we have a-a-there's guidance, navigation, and control **[guidance navigation and control]**. Um, there's a branch of it that deals with some very heinous mathematics for integrating where you are and where you want to go and how you get there…um, we don't necessarily need everybody to know that **[applied knowledge]**, but having a familiarity with what it takes **[system understanding]**…and the-the assumptions that a system like that would- would require helps people understand the needs of the entire rocket system itself **[system understanding]**.

Brent – Ok, so…not so much on the equations for the guidance, um…in a control system…but more on the application? Is that accurate?

P3 – Right, understanding what it does to the system **[system understanding]** the things that perturb it, it's sensitivities and things like that, and-and it goes to…the guidance **[guidance navigation and control]** system is a black box if you want to think about it that way…this is a system of systems, um…approach, and you have to understand enough about the system **[system understanding]** that's in there to understand how they all react, or interact with each other.

Brent – Ok. Any other systems or subsystems they should be familiar with?

P3 – Ah…just going back to the previous question of-of basics about rocket propulsion **[rocket propulsion]**.

Brent – Ok. Um…number four: if you started with a clean slate, in your opinion what are the most important subject areas an RLV technician must be familiar with?

P3 – Um…mechanical engineering **[mechanical engineering]** in general. Um…accept for when you get into electrical engineering **[electrical engineering]**. Those two areas…if you get the basics of those **[basic engineering]**, the rest of it can be taught **[internal training]** and learned **[learning on-the-job]**.

Brent – Ok. Then again you're talking about kind of learning through experience on the job there at Company ABC?

P3 – Right.

Brent – Ok. Is that the best way to teach them do you think?

P3 – We think- we think because one of the things we don't want is someone being taught how to solve these problems the standard NASA way, because that's too expensive **[budget-minded]**.

Brent – Ok.

P3 – So...um…we get addition…we get value out of having…I don't want to say reinventing the wheel but…it's like for some of these things, the company can't teach you about them because we don't know about them either **[learning on-the-job] [new ground]**. We're trusting you as being a good engineer **[independent] [self-motivated] [basic engineering]** to go figure out **[problem solving]** the most creative **[creativity]**, best, lowest cost solution **[budget-minded]**, and to teach the rest of the company how to-how to-how to solve the problem **[new ground]**.

Brent – Right…I guess I should have asked, I mean you mentioned the standard NASA way…is there kind of a baseline, uh…background that you're looking for in one of these technicians?

P3 – The base…eh seriously…the baseline that we look for is…are you a good engineer **[basic engineering]** and have you built something **[homebuilding] [fabrication] [hands-on experience]**. Not studied something – actually built something…whether it's a car **[experience diversity]** or a rocket or a satellite or…ya know it doesn't really matter. We want to see that you're willing to pick up a welding torch **[welding]**, um…and-and-and figure out how to solve the problem **[problem solving]** with your hands **[hands-on experience] [fabrication] [attitude] [self-motiated]**.

Brent – So it's all about having build hardware in some capacity?

P3 – Yes.

Brent – Ok. Um…any other, for question number four there, any other subject areas…ya know, if money was no object for training?

P3 – Hypersonics **[aerodynamics] [hypersonic aerodynamics]**.

Brent – Hypersonics are a big one for you?

P3 – Yeah.

Brent – Alright, and then this last question number five is kind of a catch all: with regards to RLV technicians, what have we not discussed that you feel is important?

P3 – Project management **[project management]**.

Brent – Ok, what do you mean by project management?

P3 – Having…understanding that your deliverables effect the company, and effects other deliverables and understanding where your tasks…understanding that…the process of building an RLV is just as much an engineering process **[engineering processes]** as actually, you know, bending the metal and figuring out the-the-the problems **[problem solving]**. Um…A lot of engineers assume that somebody else is going to tell them when things are due…and, and that's not the case **[independent] [self-motivated]**. We need engineers that understand, um…why due dates are what they are **[fast-paced]**…understand what slippage means to the rest of the project **[project management]**.

Brent – Ok. That makes sense…if you uh…delay one step in that process then the whole thing can be delayed so you'd want them to be conscious of that.

P3 – Right, but if one of the things we find it's hard for them to understand is that…um…a delay is not strictly linear. That certain things, if they delay…cause other things to take even longer than were originally planned **[project management]**.

Brent – Hmm. Ok.

P3 – If-it's it's it's dependencies again. It's the same way that the vehicle is a system of systems **[systems understanding]**…when you perturb any one of those things then all of your assumptions about how that system works fades.

Brent – Right. Ok, um that's all the scripted questions I have. If there's anything else you'd like to add…um…again the focus of this study is trying to get a picture of 'what is a reusable launch vehicle technician.' Um…and-and the way I'm going about it is asking some of these companies that are, you know…creating a vehicle…well what do you think it is? Because you're the subject experts…um…so is that pretty much the picture you'd like to paint?

P3 – Yeah, pretty much.

Brent – Um…creative, cost effective solutions…have experience on hardware…you'd like to see them have some rocket propulsion training…and some supersonic or hypersonic training…

P3 – Right, yeah, that's pretty much it.

Brent – That's pretty much it. Ok, um…

P3 – And if you can find, if you can find somebody like that let me know…

Brent – Hahaha, ok…I'm going to go ahead and stop the recording then, unless there's anything else you'd like to add on the record?

P3 – Nope, that's it. And I'm just about at my stop, so I'm going to have to drop off. Is there anything else we need to do real quick?

Brent – Um, no that’s it. I’ll end the recording then…

END RECORDED INTERVIEW

Date:	2/16/2010
Time:	3:40PM
Interviewer:	Brent Vlasman
Interviewee:	Participant (P4)

Brent – Ok this is Brent Vlasman for the interview with the reusable launch vehicle maintenance technicians project. I'm interviewing P4, and I do have your permission to record this, correct?

P4 – Yes you do.

Brent – Ok. Well let me go ahead and read you the opening statement of the interview protocol, and then if you have any questions we can answer them, and if not we can start with the questions after that.

P4 – Alright.

Brent – So it's a couple phrases that I'm going to read you, so…here we go. Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle or RLV technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation's, Federal Aviation Administration's Office of

Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, that's the ah…opening statement. Um…

P4 – Yes sir.

Brent – Do you have any questions before we begin?

P4 – No, not in particular. Um, I might think of a few along the way, but I've got a pen and paper here, so…

Brent – Ok, and if you think of some along the way just let me know, um, there's no right or wrong answer, it's an exploratory study. And if something doesn't make sense I'll try and clarify…it's a pretty painless process.

P4 – Ok.

Brent – Ok, no further questions?...Question number one: what do or what did you look for in hiring your future or current technicians?

P4 – Um, with regards to our current technicians, which is…of which I am one, um, because our system was so um, sort of one of **[new ground]**…it was not, uh, we-we actually developed the skills as we went **[learning on-the-job]**.

Brent – Ok…

P4 – Um…that were, specific to the individual, ah, systems that we were working with **[system-specific]**. However, if I were looking to hire a technician, the things that I would be looking for with regard to the qualities of the technician would be…the uh…the ability to look at the overall path **[project management]**, and-

and anticipate the needs along the way **[forecasting]**, and set up planning **[planning]**, ah…i.e. if there's a procurement of equipment, to see to it that that equipment can get you through…um, a few if not several iterations of your design process **[project management] [design involvement]**.

Brent – Is that what you meant by overall path, is the design process?

P4 – Yeah. The overall path being you know, ultimately you start from testing small vehicles with little hundred pound thrust engines **[design involvement]**. And sometime scale models. And then as you look towards scaling up, you know, when you look forward in-into the equipment needs and the logistical needs **[project management]**, that you as a- as an RLV technician are looking to implement the best possible processes **[process management]** and equipment…ah…that will-that will push you through several iterations **[planning] [flexibility]**. That way you're not looking at…'ok, this works good enough at this level…'

Brent – Ok.

P4 – Because then you- then you minimize the amount of redesign **[design involvement]** that you have to do in – with regard to support equipment **[planning] [forecasting]**.

Brent – Ok, that makes sense. Is there anything else you look for in technicians right now?

P4 - Um, right now with regard to technicians…um…

Brent – So if you were to hire somebody, what would you want, what would you want them to…

P4 – I would want them to have, ah…I would want them to have a wealth of experience in several different, uh, in several different areas **[broad knowledge-base] [diversity of experience]**. And the ability to think on their feet **[creativity] [fast-paced]**, and uh…and adapt. Adaptability is critical **[adaptability] [flexibility]**. Um, because sometimes one iteration might, er – one path that the vehicle is going down may end up being scrapped.

Brent – Ok.

P4 – And also I'd look for somebody that was capable of checking their pride at the door **[humility] [self-awareness]**.

Brent – Hahaha, ok, checking pride at the door – got it.

P4 – Yeah.

Brent – Ok, moving on to question number two: what additional knowledge areas would you like your technicians to possess?

P4 – Um, the knowledge areas that I would like my technicians to possess would be basic construction skills **[construction skills]**. Um…because in a lot of basic construction you're dealing with similar things that you do in an RLV program. Basic construction skills **[construction skills]** being: a familiarity with wiring **[wiring]**, electrical wiring **[electrical] [electronics]**, a familiarity with plumbing **[plumbing]**, and also, ah…certain structural, eh some structural familiarity **[structural]** to ah, enable to do some light-weight **[weight-reduction]** strengthening **[light-weight strengthening]**…i.e. if you need to add a certain amount of strengthening to, for example a reusable launch vehicle, that will support the load, you want it to be light weight **[light-weight strengthening]**. So light weight strengthening of structures **[structural]**, that sort of thing.

Brent – When you say construction do you mean, like residential, like building a house construction?

P4 – Residential, commercial **[construction skills]**…

Brent – Ok…

P4 – It's amazing how often ah, that sort of thing comes into play. It's-it's-it's-it's not so much the – the actual skills themselves, it's the thought processes **[construction thought process]** that people that are experienced in those skills develop.

Brent – Interesting.

P4 – As they look at-at different structure **[structural]**…they, ah…the thought processes **[construction thought process]** that is…are 'where is the load going to go' **[basic engineering]** you know 'what do I need to do to support that load?'

Brent – Huh, that's interesting, I mean that makes sense when you describe the "sub-characteristics."

P4 – Yeah, the sub-characteristic being, is being able to analyze, 'ok, what does this need to make it stronger **[light-weight strengthening]** but not add a lot of weight?'

Brent – Ok…any other additional knowledge areas?

P4 – Well, uh the other additional knowledge areas one of the things that I've been a beneficiary of is for the last two years I've worked in cryogenics **[cryogenics]**.

Now, I would recommend that anybody who is ah…an RLV technician, be in the thought process of whatever type of propellant **[propellant] [propellant handling]** that they're- they're using.

Brent – Ok…

P4 – In our case – in our case it's cryogenics and-and alcohol **[cryogenics] [propellant]**. Or cryogen plus another cryogen. For example oxygen and uh…liquid- liquid methane. So ah…a good familiarity with cryogenics **[cryogenics]**, with handling of cryogenics **[cryogenics handling]**, and also with the logistics **[logistics]** of, 'what is the plan, at the-at the point of launch, what is the plan? **[project management] [planning]** At-at the- at the point of launch, what is the plan? What do I need, what I as a technician need to make sure is there so that I can make sure that I have the appropriate tankage, the appropriate amount of materials on hand, and that we're not short, you know, we're not short any product **[project management] [planning]**. Especially if you're going to travel, for example we traveled about 700 miles to do launches. It took a considerable amount of advanced planning **[planning]** to make sure the product, that all of the propellants **[propellant]** were there, and everything that we needed to support those operations.

Brent – Ok, so that kind of goes back to…

P4 – 700 miles from our home base…

Brent – Right, so planning is very important in that situation.

P4 – Oh absolutely. And you want somebody that –that can make a plan **[planning]**, follow through, but also be flexible **[flexibility]**. Flexibility is absolutely critical **[flexibility]**, especially in an experimentation process.

Brent – Ok.

P4 – And – and reusable launch vehicles are-are really really new **[new ground]**. Ah, and I come from the perspective of, you know, small company type **[entrepreneurial mindset] [attitude]**, ah…rather than, you know, the gigantic, you know, the –the giant monoliths of aerospace that have an office in, you know, ten different cities.

Brent – Right.

P4 – You know we have think like snails, or we have to think like military people. Military people have to bring with, you know, what, bring with them what they need to accomplish what they need to accomplish **[planning] [logistics]**.

Brent – Ok. Um…getting into question three, um: what systems or subsystems should an RLV, should RLV technicians be familiar with?

P4 – Ah, the RLV technician, the primary thing that an R-RLV technician should be familiar with is, they should have an overall familiarity with how each of the subsystems interact to make the whole platform **[system understanding]**. Ah…it's-it's critical to know, for example, roll control thrusters **[roll control thrusters]**. What are they, where are they, uh…whe-when…and part of it is kind of proofreading the system I like to, is what I like to call it – it's sort putting my eyeballs on each individual item **[component knowledge]** and then trying to see, ok, have I even looked at it the right way **[system understanding]**. Do we have everything connected properly **[diagnostics]** [**thoroughness]**? Uh…the subsystems, ah…wiring harnesses **[wiring] [electrical]**, im-important to know how to build one. Ah, in case you run into the need for some quick in-field fabrication **[fabrication]**.

Brent – Ok.

P4 – Um…subsystems would be, ah…well really the loading platform for loading the vehicle **[propellant handling]**. Also trying to minimize whatever in the loading process **[process management]**…for the vehicle itself…you want to minimize what's on the vehicle **[weight reduction] [design involvement]**. If it has to made heavy **[weight reduction]**, you know, try an-try and make it ground support equipment **[design involvement]**.

Brent – Ok, when you say "loading" what do you mean by that?

P4 – Uh filling the vehicle with propellant **[propellant handling]**.

Brent – Ok so propellant loading.

P4 – Yeah. Which is my primary focus in-in the uh, operations that we conduct.

Brent – Ok. Um, so you mentioned wiring, um…some structure…what other, any other subsystems that you…you mentioned subsystems making the whole…are there any other specific subsystems that you'd like them to know about?

P4 – Well I think one of the, one of the um…the…let me think…um, as far as subsystems, ah…you want, you want to be familiar with ah, for example valve actuators and that sort of thing.

Brent – Ok.

P4 – Uh you want to be able to look at a valve actuator from the outside and know that it is on correctly **[diagnostics]** and that your valves are positioned correctly **[component familiarity]**.

Brent – So would you call…

P4 – Not always…

Brent – Go ahead…

P4 – I'm sorry go ahead…

Brent – I was saying would you call that hydraulics? Or is that a different system?

P4 – Well actually we're kind of getting into uh, question four.

Brent – Ok, sure alright here we go…transition, beautiful! If you started with a clean slate, in your opinion what are the most important subject areas an RLV technician must be familiar with?

P4 – The, I think the two most important, ah…systems that an RLV technician should be familiar with is electronics **[electronics]** and plumbing **[plumbing]**. And one of the things I wish that I had a greater sense of…for myself, for my own knowledge, is electronics **[electronics]**.

Brent – Ok.

P4 – Plumbing- plumbing is…rocketry is plumbing **[plumbing] [rocket propulsion]**. Um…making a making a launch vehicle is essentially pluming **[plumbing]**.

Brent – Ok.

P4 – Ah, it's all of, it's all of the lovely electronic **[electronics]** things that make it work beautifully **[avionics]**.

Brent – Ok, what do you, what do you mean by electronics?

P4 – Um, for example, ah…for example in-internal to valve actuators would be valve positions sensors **[electronics]**…ah…the ah, and knowing-knowing those systems very well that are, are inherent to your specific systems **[system understanding]**.

Brent – Ok.

P4 – Um…ah, the electronics **[electronics]** with regard to ah…just being able to, you know, stick an ohmmeter on something **[hands-on] [troubleshooting]** and know what it's telling you **[applied knowledge]**.

Brent – Ok so some troubleshooting, maybe?

P4 – It's being able – being able to troubleshoot **[troubleshooting]** a problem that- if that- if a problem arises **[problem solving]**.

Brent – Ok.

P4 – Um but specifically, you know, being able to know where substance should be located, what to cleanup that sort of thing.

Brent – So if you were to summarize, I think you said it from the beginning, electronics and plumbing, those are your big ones?

P4 – Yeah, and an, an incredibly healthy dose of curiosity **[curiosity]**.

Brent – Ok.

P4- It-it takes a…one of the things you have to remember, that, you're not the smartest guy out there **[humility] [self-awareness]**. You have to, we-we have the opportunity to stand on the shoulders of giants. With, you know, Von Bron and Goddard, and people like that, and it-you you want to make sure that when you, when you go out there you don't presume that you know everything **[humility] [self-awareness]**.

Brent – Mhm.

P4 – Um…that's why you have to have a decent dose of curiosity **[curiosity]**. Um, that healthy dose of curiosity is particularly…uh, important, in building the whole system **[system understanding]** because then…if-if you understand how your, you know, for example, roll control thrusters **[roll control thrusters]** react based on the center of gravity with a gimbleing system, you know, what is it going to do? Is it going to make the gimbles want to shove a little bit in one direction, what is that going to do to the overall control of the vehicle **[system understanding]**?

Brent – Ok.

P4 – Um…aerodynamics **[aerodynamics]** would be a good healthy area to get some familiarity in.

Brent – Ok.

P4 – because, you you you know, as an RLV technician you want to look at, 'ok, what are better aerodynamic shapes **[aerodynamics]**?' But then at the same time, considering your design **[design involvement]** and what is your projected path further down the road **[planning]**, ok, do we want to be able to cart this,

this…vehicle from place to place on a trailer and simply go over the road **[logistics]**. Or are we going to have to air-ship it, are we going to have to, you know, get a super-guppy and to haul, you know, parts of it…parts of it around…**[logistics]**

Brent – Right…

P4 – Um…and for, you know, for our purposes, our intent is to try and keep it under eight and a half feet **[design involvement]**. Because eight and a half feet is the limit of a, you know, of a vehicle's width for going down the highway without a wide-load marker [**logistics]**.

Brent – Right. That makes sense. You're also involved with…it sounds like…design issues as well as maintainability issues.

P4 – Well maintainability, partly because our designs are ridiculously simple **[design involvement]**, ok…

Brent – Haha, ok…

P4 – Because if they were any more complex I think it would all go over my head.

Brent – Hm…ok…

P4 – Um…and then I would, then I would kind of get key-holed into that single slot of…um…you know, put the fill ports on this side of the vehicle so we can, so I know where to connect up hoses to or I know what connectors we need to put here.

Brent – Ok.

P4 – You know, that sort of thing. Um, the key is to, is to think of, think - think long term **[planning]**…over…I mean, let me see if I can phrase this the best way possible.

Brent – Sure.

P4 – Making good decisions early helps you last longer term **[design involvement] [planning] [forecasting] [project management]**.

Brent – Ok.

P4 – Um…the, the, you have to be thinking of…what, you know, what is this the intended purpose of this vehicle **[design involvement]**. Are we going to lob some instruments up and simply do weather readings or something like that. You know, or, are we gonna try and put you in a reusable launch vehicle. Well then you run through a whole other system of how many redundant systems do we want with regard to safety **[safety]**. So you think of things like safety **[safety]**. Safety being the first, most critical thing **[safety-critical]**.

Brent – Mhm.

P4 – Um…the-you-you know…you want to be able to transport it safely **[logistics]**, you want to be able to fly it safely **[safety]**, you want to be able to bring it home safely **[logistics]**.

Brent – Yeah, definitely. And that makes sense to have your, as much thought at the beginning of the design as possible so that your iterations are less…significant or less severe.

P4 – Well and that, the criticality of that is knowing the…back to the ability to look at the overall path **[planning] [project management] [design involvement]**.

Brent – Right.

P4 – You know, when you look at the overall path **[project management]** is what you're doing right now are these steps that are moving you down that path or are you just sort of marching in place.

Brent – Right so it sounds like planning is high up there on the priority list of something that you want a technician to be conscious of.

P4 – Yes, absolutely. Ah, planning, planning is pretty critical **[planning]**. Ah, because uh…in a lot of case, in a lot of cases, for example in the larger aerospace firms you have people that do nothing but qualify wire. And for-for thirty years they'll qualify a crimp connection…on a launch system.

Brent – Ok.

P4 – The saddest part is that that launch system…that crimp connection that they've been qualifying for thirty years…when they fire that rocket, it's gonna go in the ocean.

Brent – Yeah.

P4 – And it's-it's never going to be reused. Well when you look at your system you want something that has simplicity of operation and reusability **[design involvement] [system understanding]**. Hence, the R in RLV…

Brent – Right.

P4 – Uh…but I think reusability is…simplicity is critical **[design involvement]** in making the reusability of the system.

Brent – Ok.

P4 – You want, you-you-you want simplicity so that you can verify that things are-are-are on there correctly **[diagnostics] [safety]**.

Brent – Right.

P4 – And you-and you want overall familiarity with the vehicle **[system understanding]**.

Brent – Ok. Um, kind of a catch all question here at the end, this is the last question. With regards to RLV technicians, what have we discussed that you feel is important?

P4 – That was the biggest thing that I had a hard time answering. Because I did you look at your…at the document you sent Person ABC…um…

Brent – Well let me clarify…there's…

P4 – The biggest key…

Brent – Go ahead…

P4 – Oh I'm sorry go ahead…

Brent – No that's fine…

P4 – I think one of the, one of the larger keys is an open mind **[open mind] [attitude]**. And, and part of it is-is, part of that is, you know, checking your pride at the door

[humility], and having an open mind **[open mind] [attitude] [flexibility]** to not always being right **[self-awareness]**.

Brent – Ok. And why is that important?

P4 – Um, I think that…I think that within the R, the reusable launch vehicle community, there are…there are a lot of compromises made where people say ‘ok this was good enough to get us there’ and so that’s become sort of the rocket bible. Just because it was good enough to get there. Uh…if you keep an open mind **[open mind]**, there could potentially be a much better, much simpler than just plain old good enough **[creativity] [new ground]**.

Brent – Ok. So it’s…

P4 – Um…

Brent – Or…maybe…receptiveness to new ways of doing things?

P4 – Yes, exactly.

Brent – Ok.

P4 – Um…there…for as much as, for example, things like metallurgy **[metallurgy]** have changed in the last, you know, since we went to the moon, uh…there’s there’s some better manufacturing processes **[manufacturing processes]** out there. They’re better-they’re better, better welding **[welding]** systems just for putting things together **[component assembly] [manufacturing processes]**…

Brent – Right…

P4 – That have come into play. And-and so you have to, you try to take advantage of emerging-stuff that's emerging, proven technology **[new ground]**.

Brent – Right.

P4 – That - that works well. Um…the loading panel on my…on-on my work station when we're doing uh…when we're doing our rocket operations looks like sort of like a-ah…you know, a German U-boat…from world war two…with it-with sort of a myriad of valves. But if you take a few moments to really look at it, look at the labels and what they say…I tried to make it **[process development]** simple enough, that anybody could step into that position, follow the checklist **[process management]**, and make the-and-and make the fill **[propellant handling]**.

Brent – Ok. So, with this last question, and there's no right or wrong answer to it, an open mind is-is the big thing that we didn't talk about…like that I didn't specifically ask you about is having an open mind when you come in the door?

P4 – Yeah, having an open mind **[open mind]** I think is-is pretty critical because you never know-you-you never know what is going to hit you **[flexibility]**, you know, some of the best ideas I get are in the shower in the morning.

Brent – Right…

P4 – And…being able to, to trus-to simplify that, and just, I mean, kee-keeping your mind open **[open mind]** to, 'what could I, as a technician, be doing better, day in and day out **[continuous improvement]**, that would help the overall progress of the team **[team skills]**?'

Brent – Ok. Um, I think that makes perfect sense. Is there anything else you want get, um, while I have the record going?

P4 – Um…can't think of anything off the top of my head.

Brent – Ok.

P4 – Um…is there anything, are there any other questions that you might have?

Brent – No, that's-that's all I need for this study. If you don't have anything else to add I'll go ahead and stop the recording then.

P4 – Ok.

Brent – Ok.

END RECORDED INTERVIEW

Date:	2/16/2010
Time:	5:10PM
Interviewer:	Brent Vlasman
Interviewee:	Participant 5 (P5)

Brent – Ok, and this is Brent Vlasman interviewing P5 of company ABC, um for the reusable launch vehicle technicians project. Um, P5 I do have your permission to record this, is that correct?

P5 – That's correct.

Brent – Ok, um, what I'd like to do now is read through the opening statement. Um, in the document that I sent you, and then answer any questions you have before we start, and then we'll get into the interview questions.

P5 – Very good.

Brent – The opening statement goes as follows: Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes. The purpose of this study is to identify important subject areas for the training of reusable launch vehicle or RLV technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation's, Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles. Ok, any questions before we get started with the interview?

P5 – No I'm good, thank you.

Brent – Good to go, ok question number one: what do or what did you look for in hiring your future or current technicians?

P5 – Well our current technicians are a conglomerate of people who originally started out as having the same mindset **[mindset] [attitude]** or the same passion **[passion]** to be able to develop our rocket vehicle technology on a volunteer basis **[enthusiasm]**.

Brent – Ok.

P5 – None of us were paid at the onset. We all wanted to create something special **[passion]**. And by special to us that meant something that would hop up and fly and be reusable so that we can conduct certain, uh, activities…with the hardware that were unique to reusability and-and fast turnaround.

Brent – Ok.

P5 – And as we kept those things in mind as we were going through all this, that the people that were involved had no previous training whatsoever in the specific field of aerospace **[self-taught]**.

Brent – Really?

P5 – They learned how to handle the chemicals **[chemicals] [chemical handling]**, ah…by the basic standards that were already in place for industrial use **[industry standards]**.

Brent – Ok, so you took basically a volunteer crew and taught them…based on available materials?

P5 – Well…I have to include myself in that group even though I'm one of the principles at Company ABC right now I'm going to be in charge of training a lot of the people that come through here.

Brent – Ok.

P5 – Ah…at the time none of us had any training whatsoever **[self-taught]** so we were teaching ourselves as well as each other **[learning on-the-job]**.

Brent – Interesting…ok, um, so…now looking towards the future what do you, or what would you ideally look for in hiring a technician?

P5 – If…someday there were a program, let's say there were a two year school that trains technicians like today you see electronics technicians and – and drafting technicians and you see technicians of different-different types in industry…if there were a two-year school that were to train technicians **[2-year program]**…the stroke of their training would be anywhere from documentation **[documentation]**…to an understanding of what stored energy is **[stored energy]**, and how different types of stored energy **[stored energy]** can be…uh, dangerous **[danger]** so that a general idea of handling things **[propellant handling]** that are, let's say, pressurized gases **[high pressure systems]**…that's a stored energy **[stored energy]**, which is, uh…potentially very dangerous **[danger]**…

Brent – Ok…

P5 – Uhh…and-and fittings **[fittings] [plumbing]** and the disassembly and assembly **[assembly/disassembly]** of parts **[component knowledge]** that may have already been in the field or what might go into the field and-and how…the details of-of-of-of those parts, in their operation…uh, pertain to different levels of safety **[safety]** either before or afterwards. For instance, uh, I-I grew up in the aviation industry as a lineman **[aviation-like]**, and there were periodic times when I would be in the shop with the A and P mechanics…

Brent – Mhm…

P5 – And I remember them…there was probably five or six extremely expere-experienced, ah…aviation mechanics, disassembling this strut that they thought may have failed. With all the experience standing there watching what was going on, every single one of them overlooked the idea that the strut was still pressurized. And they couldn't figure out why one of the snap rings was stuck in so hard. So as one of the gentlemen was tapping the snap ring to pop it out, uh…nobody realized what was going to happen, or even imagined the possibility of their being any danger…and then not too far into the process as he was tapping the snap ring out it came loose and subsequently the inside of the strut came out rather…fast and hit a gentlemen in the chest.

Brent – Oooh.

P5 – That put him into a-a cardiac arrest type situation. Uh…where he survived it, but it didn't do him any good – he was really well bruised and of course the embarrassment of the rest of the gentlemen standing around not…going through a specific procedure with that particular part that they all knew better was what really, I found, interesting about that. Now…we can run into the same problems here when we're working on-on rocket **[rocket propulsion]** technology.

Brent – Ok.

P5 – And it's typically not the really big dangerous **[danger]** operation of propellant loading **[propellant handling]** or something like that that ends up being the hazard that hurts someone. It's simple little things that take you off your normal procedure **[procedures]** that causes problems.

Brent – Hm.

P5 – For instance, during the ah…Lunar Lander challenge we landed the vehicle rotated a hundred and eighty degrees off from where it was intended to be because of a roll thruster **[roll thruster]** problem. Well when we pulled the service vehicle up, we could not reach everything appropriately, so we had to go through a procedure **[procedure]**, I mean we had to step off of the main procedure and try and go through this process still within our window of two and a half hours and-and-get things done within an appropriate amount of time. Well unfortunately we skipped a couple of steps on venting things down **[high pressure systems]**…and when we were beginning to load the propellants **[propellant handling]** back into the vehicle and going into the actuator checks, when the actuator for the…pressurization system **[high pressure systems]** was activated…two things that ended up having 300 psi on the other side…uh, flailed wildly…and contacted two of our team members **[high pressure systems]**. It wasn't a life threatening situation…but it was certainly dangerous **[dangerous]** to say the least. And there are things like that that you would really want to be able to train your-your technicians to recognize **[diagnostics]** because those are the types of situations that causes problems **[safety]** **[danger]**.

Brent – Ok.

P5 – Uh, obviously you want to train them in many other areas as well, but those are some of the key areas.

Brent – Ok, um…so kind of talking, and then getting more specific with this training, this question number two is a good transition: what additional knowledge areas would you like your technicians to posses? And you can include yourself in there if you'd like.

P5 – Ok. First of all, knowing and understanding what a procedure **[procedure]** is and how to generate one based on what you're doing **[procedure creation]**. How to, um…manage a procedure **[process management]** during the process, and keep a living document **[documentation]** so that things can be added to and or taken away from as the uh…system evolves **[system evolution] [process management]**. And then in addition to that you want the person to understand stored energy **[stored energy]**, uh…capabilities, stored energy potentials **[stored energy] [propellants]** [**system understanding]** such as pressurized gases **[high pressure systems]**. Um…chemical **[chemicals]** stored energy **[stored energy] [propellants]** for instance if you're working with something like hydrogen peroxide **[chemicals]**, it has an inherent stored energy **[stored energy]** that's rather, ah…dangerous **[danger]**…ah, especially if there are contaminants **[contamination]** involved it can go from just a benign liquid sitting in a container, to over pressurizing **[high pressure systems]** and exploding **[danger]** very very rapidly depending on, uh…contaminant **[contamination]** content and cause serious problems **[safety]**. And then also you have cryogenics **[cryogens] [stored energy] [propellants]** and then you have oxidizers **[oxidizers] [propellant] [stored energy]** mixed with fuel **[fuel] [chemicals] [stored energy]**, so different types of stored energy **[stored energy]** there. So stored energy is key **[stored energy]**.

Brent – Ok.

P5 – And then you-you go over and look at the rocket systems **[rocket propulsion]** themselves as mainly plumbing oriented **[plumbing]**. And then you also have electrical systems **[electrical]**, but you want to be able to understand…ah, plumbing issues **[plumbing]** – how a valve works, how the-how the valve itself actually seals **[system understanding]**, what types of things you would see if the valve was failing **[failure recognition]** and what types of failures you would see under certain conditions **[diagnostics]** **[troubleshooting]**.

Brent – Ok.

P5 – Uh, and then just uh in general materials compatibility **[materials compatibility]** **[contamination]**. That would be a very important part of it.

Brent – And by materials are you talking primarily structure of the vehicle? Or…

P5 – No.

Brent – No?

P5 – No, I' talking about materials that are in contact with oxidizers **[oxidizers]** or fuels **[fuels]** that may or may not be compatible **[materials compatibility]** with those oxidizers **[oxidizers]** or fuels **[fuels]** **[propellant handling]** **[contamination]** **[chemicals]**.

Brent – Ok…

P5 – For instance, some materials may be compatible **[materials compatibility]** with ethylene **[chemicals]**, but not with alcohol **[chemicals]**. Some materials may be compatible **[materials compatibility]** with-with the fuel **[chemicals]**, but not with the oxidizer [**oxidizers] [propellant handling] [contamination] [stored energy]**.

Brent – Hm.

P5 – Some materials may be compatible **[materials compatibility]** at room temperature with peroxide **[chemicals]** but they won't be compatible with-with uh…lox **[stored energy] [propellants] [oxidizers]**. So there's a lot of differences there - in materials **[materials compatibility]**.

Brent – Ok, any other additional knowledge…I mean that's a great list, are there any other knowledge areas you'd like to include?

P5 – Let's see…I think I ran a pretty…a pretty large range **[broad knowledge-base]**.

Brent – Ok, and if you think of something, we can come back to it.

P5 – Alright.

Brent – I'll move on to the third question: what systems or subsystems should RLV technicians be familiar with?

P5 – For the most part, the RLV technicians are going to be…in direct contact with propellant loading and unloading **[propellant handling] [stored energy]**, and then pressurization and depressurization **[high pressure systems]**. Those particular operations would involve being familiar with the, the plumbing system mainly **[plumbing]**, and then secondarily some of the electrical system

[electrical] and how those – those, different actuators work for valves and such **[plumbing]**, and then, uh…materials compatibility **[materials compatibility]** as well. So if you have a leak in a certain area, does that leak pose a problem to the flight or is it just an incidental problem **[system understanding] [safety] [danger] [diagnostics]**.

Brent – Ok.

P5 – Ah…if you have a small oil drip under your engine, that wouldn't necessarily concern me. But if you had ahh-ahh an oil drip or an oil leak that was mixing **[materials compatibility]** with some form of liquid oxygen **[chemicals] [oxidizer]** or other form of oxidizer in a rocket situation **[rocket propulsion]**, that would be potentially very harmful, or dangerous **[danger] [system understanding]**. So you'd wanna know, know a lot about material compatibility **[material compatibility]**, and then, and scenarios with the propellants **[propellants]**, and with-with the plumbing **[plumbing]** itself.

Brent – Ok. So most of the compatibility you're talking about is the propellants or the chemicals interacting with each other?

P5 – Yeah, and then of course you want to have a good understanding of plumbing **[plumbing]** side of things as well because you…virtually every connection needs to have a, a vent **[high pressure systems]**…associated with it so that once propellant loading **[propellant handling]** is terminated and the valves are closed [**plumbing]** you vent the connection before you, uh…open it. So there are, there's stored energy **[stored energy]** in there and sometimes in pressurized fluids **[high pressure systems]** if it's a cryogen **[cryogens] [propellants] [chemicals]** and it's been boiling **[high pressure systems]** off in a trapped space you could potentially have a dangerous **[danger]** situation. Uh if the ball valves aren't vented appropriately **[plumbing]**, uh you could have a valve that closes and have, uh…liquid oxygen **[oxidizers] [propellant handling]** trapped in it and if it's not vented it could build pressure [**high pressure systems]** to the point where it explodes **[danger] [safety]**. And the same thing with peroxides **[chemicals] [propellant handling] [materials compatibility]** and-and stuff like that. So…I mean it's really important to understand the nature of, of the material **[propellant handling] [materials compatibility]** you're working with, and-and what types of requirements it has of the plumbing **[plumbing]** as well.

Brent – Ok. Um, that makes sense. Ok so here's kind of a-a bigger picture question number four: if you started with a clean slate, and maybe you are starting with a clean slate, in your opinion what are the most important subject areas an RLV technician must be familiar with?

P5 – Most important subject areas that they must be familiar with…RLVs are unique because you're dealing with propellants **[propellants]** and you're also dealing with plumbing **[plumbing]**, and the plumbing you're dealing with generally is-is either going to be a very reactive material **[materials compatibility]** such as peroxide **[chemicals]**, or a cryogen **[cryogens]** such as liquid oxygen **[propellants] [stored energy]**. So…you-you probably want to have some sort of industrial knowledge **[industry standards]** about the handling **[propellant handling]** and function **[propellants] [chemicals] [fuels] [oxidizers]** of different types of materials **[materials compatibility]** and handling equipment for those…those propellants **[propellant handling]**. And then as it applies to the vehicle you'd wanna be able to maintain uh…a certain level of safety **[safety]** in-in the assembly **[assembly/disassembly]** and the-the loading **[propellant handling]**. I don't know, perhaps I'm getting away from-from exactly what we need there but…

Brent – Oh no that's good. See the beauty of this, you know, study is that there is no…it's very exploratory, it's kind of…an uncharted territory and there's no wrong answer.

P5 – Right.

Brent – So, from what I'm hearing it's a lot of the plumbing side, um…material compatibility, and a knowledge of how to safely handle some of these uh…propellants? Would that be correct?

P5 – Right. Yes.

Brent – Ok. Um…if you started with a clean slate, any other subject knowledge areas that you'd like an RLV technician to be familiar with?

P5 – Well it…from an RLV technician perspective I can't think of anything right off the bat other than you know, they'd progress through just being a technician to being a crew chief to…whatever the case may be, but…

Brent – Ok.

P5 – Understanding the whole system in general **[system understanding]** is probably not going to be possible for every single one of the technicians on the job **[system specialization]**, so…uh…

Brent – Right…

P5 – It's just a matter of exposure **[learning on-the-job]**. I-I-I don't know of any other way to-to put it.

Brent – Ok.

P5 – It-it, you know it…when I got out of tech school, originally, um…I wasn't like this super-smart wiz guy that would go out and change the world with my knowledge of electronics **[self-awareness] [humility]**. Um…but I certainly had the-the tools I needed to progress through, uh…the requirements of my new position **[learning on-the-job]** and being able to apply that **[applied knowledge]** to troubleshoot **[troubleshoot]** hardware and whatnot. So it's gonna be the same thing, they're-they're gonna need to have a-a basic understanding of plumbing **[plumbing]** – how it goes together **[assembly/disassembly]** what's good and what's bad **[system understanding]** and what kind of bad things can happen **[dangers]**. Um…

Brent – Ok.

P5 – And just kinda…train from there **[learning on-the-job] [internal training]**.

Brent – Yeah, and I'm finding that a lot of these…roles, like you said, are very specialized and they'll have to do some on the job training to really understand the systems.

P5 – Well…yeah, I mean, uh…internships are great. Haha….when a student comes in and-and they're able to work with actual rocket hardware **[rocket propulsion]**, and then they go back to their-their class and they say hey we did this that and the other thing and they ask their instructor why did we do this in particular, and he-he might have some knowledge that…answers the question there in his brain that wouldn't-wouldn't necessarily…just come out without the student the appropriate question.

Brent – Right. Ok. Um…number five is my catch all question here: with regards to RLV technicians, what have we not discussed that you feel is important?

P5 – Well when I was in the aviation industry I did take some training…um, that qualified me to be a what was called a lineman. And a lineman is basically an RLV technician except for aircraft **[aviation-like] [lineman similarity]**.

Brent – Ok.

P5 – And we-we covered what was required for fueling the aircraft, either with av-aviation gasoline or with jet fuel. Uh, we also learned how to service the oxygen systems onboard, and what the sy-the basic safety requirements were for each of those. And these were-were training programs that were fairly extensive, it was probably…forty hours or so of classroom instruction and some practical stuff and then you had to take a test and…then you got this nice little certificate that you could put on your wall saying that you were a qualified lineman.

Brent – Ok.

P5 – Well I think the same things would apply to being qualified RLV technician **[aviation-like] [lineman similarity]**. You'd wanna go through some formal training, exercise that would be…you know, ah a-reasonable, ah…bit of information that would have been accumulated over the years so far what we've done with-with our technology.

Brent – Ok.

P5 – Now whether or not we have enough information to make that happen effectively, uh…I think we're close. I don't know if we have an exhaustive set of information…Company ABC probably has a unique situation that we've worked with more different propellant **[propellants]** types than virtually anybody in the world…uh, in any aerospace application.

Brent – Hm…

P5 – So this small team of X guys kind of knows their stuff when it comes a very wide variety of propellants **[propellants]**.

Brent – That's pretty impressive. Ok, well…if there's anything else you'd like for me to capture on the record, um…is there anything else you'd like to get across, input with regards to an RLV technician in general?

P5 – Right off the bat, I-I'm I-m not thinking of anything except for possibly the regulatory **[regulatory involvement]** side of things. There are…there are NFTA documents **[industry standards]**, ah, for instance if you're working on airport an FPA407 would be something you refer to uh…for propellant…handling **[propellant handling]** or for fuel storage **[fuel storage]** or for oxygen storage **[oxygen storage]**. Uh, but then there are other, uh…other NFTA documents **[industry standards]** that are specific to liquid oxygen **[propellant handling]**, there are some that are specific to liquid methane **[propellant handling]**, and then you've got DOT regulations **[regulatory involvement]** so there might be some of these things that you get familiar with looking at the different, uh…ah…MSDS **[industry standards] [chemicals] [safety] [materials compatibility]**, and-and other safety protocols that are generally recognized out there if you're gonna, I mean through uh…NFTA. And-and knowing how to apply that information **[applied knowledge]** in an appropriate setting.

Brent – Ok and what is…

P5 – And what we…what we discovered is that even the guys at NASA…they-they handle things with kitten gloves to the point where they really don't understand what it is they're dealing with they treat it with such…an overwhelming respect, far beyond what the standard of industry is, that you would think they were handling, uh…nitroglycerine **[system understanding]**. Which you don't…uh, it-it is to be respected, but it can be taken overboard **[industry standards] [safety] [danger]**.

Brent – Right.

P5 – Uh, where-whereas if you…haha…see a liquid oxygen truck **[propellant handling]** running down the road, it's something that you can park right next to…a school bus full of nuns and children on a fieldtrip, and be perfectly safe…haha.

Brent – Ok…

P5 – But when that, uh…same truck gets on site at a NASA facility, it cannot exceed five miles per hour, has an escort of two fire trucks, an ambulance, a header car and tailer car, I mean…the whole thing it –it –it gets kinda ridiculous when you see how they-they treat it.

Brent – Wow…

P5 – Whereas, you know, the standard side of the industry **[industry standards]** already has a very good grasp and an excellent safety record and…when it comes to handling these things **[propellant handling]** it's um, it's uh…much less intense.

Brent – Ok, so…I think you-you said it well it's how to appro-appropriately apply those regulations or that knowledge to the RLV industry, is going to be important.

P5 – Sure.

Brent – Ok. Um…is there anything else you'd like me to capture on the record?

P5 – Uh…I can't think of anything right of the bat.

Brent – Ok, then I'm going to go ahead and stop the recorder now.

END RECORDED INTERVIEW

Appendix C. Project Brief

PURDUE UNIVERSITY

COLLEGE OF TECHNOLOGY

REUSABLE LAUNCH VEHICLE TECHNICIAN Expertise STUDY

Brent Vlasman
Department of Aviation Technology
Purdue University

Image source: NASA National Space Science Data Center

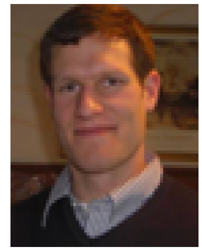
What are important subject areas for the training of RLV technicians?

Goals of the study:

- Identify important subject areas for the training of RLV technicians.
- Contribute to the commercial space industry body of knowledge.
- Start the discussion of an RLV technician training curriculum.

Table of Contents

The researcher conducting this study is Mr. Brent Vlasman. A brief introduction is provided below.



Brent Vlasman is a second year M.S. student in the College of Technology at Purdue University. His research area is emerging technology and entrepreneurship in aviation, with a focus on commercial space operations. Brent completed his Bachelor of Science degree in Aeronautical Engineering Technology from Purdue in 2008. Brent is an FAA licensed Airframe and Powerplant mechanic and private pilot.

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Interview Protocol

Opening Statement:

Please understand that your participation in this study is voluntary, and you must be 18 years old to participate. Participation or nonparticipation in this study will not affect your employment. Your responses will be kept confidential, and any quotations used in the final report will be attributed to "Participant 1, 2, 3…etc." to maintain anonymity. The interview itself should last between 20 and 25 minutes.

The purpose of this study is to identify important subject areas for the training of reusable launch vehicle (RLV) technicians. I am conducting this study for my Master's thesis. As such, I will be conducting the interviews, transcribing the audio recordings, analyzing the data, and writing the final report. Insights generated as a result of this study could benefit the companies in the commercial space industry, institutions of aviation and aerospace education, as well as the Federal Aviation Administration's Office of Commercial Space Transportation. Please answer the following questions based on your knowledge and experience with sub-orbital reusable launch vehicles.

Questions:

1. What do/did you look for in hiring your future/current technicians?
2. What additional knowledge areas would you like your technicians to possess?
3. What systems or subsystems should RLV technicians be familiar with?
4. If you started with a clean slate, in your opinion what are the most important subject areas an RLV technician must be familiar with?
5. With regards to RLV technicians, what have we not discussed that you feel is important?

PURDUE UNIVERSITY

COLLEGE OF TECHNOLOGY

Brief Methodological Background

- This is an exploratory, qualitative study attempting to identify subject areas that are important to the training of RLV technicians (Sekeran, 2003).
- Participants will be selected based on their knowledge of aerospace technology (Wiggins, 1999).
- Data will be gathered through telephone interviews with participants. Interviews will be recorded and transcribed for analysis (Patton, 2002).
- Data will be analyzed using Open-coding and Grounded Theory (Strauss & Corbin, 1990).

A research paper will be published to disseminate the results of the study.

References

Patton, M. Q. (2002). *Qualitative Research and Evaluation Methods.* Thousand Oaks, California: Sage Publications, Inc.

Sekeran, U. (2003). *Research Methods for Business: A Skill Building Approach.* New York: Wiley.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* London: Sage.

Wiggins, M.W (1999). *Aviation social science: Research methods in practice.* Aldershot, UK: Ashgate.

Appendix D. Code Frequencies

Table D.1.

Codes and Frequencies from Interview 1

Codes	Frequency	Line Number
Attitude	9	36, 40, 44, 49, 58, 97, 105, 380, 486
New Ground	7	42, 45, 163, 170, 422, 427, 474
Flexibility	2	50, 96
Experience Diversity	10	51, 53, 58, 64, 97, 123, 125, 339, 359, 483
Mechanical Aptitude	1	53
Enthusiasm	2	58, 486
Machine Shop	2	65, 124
Racing Experience	1	66
High Performance	2	70, 469
Safety Critical	5	71, 111, 271, 475, 506
Hands-on Experience	1	90
Welding	1	94
Experience	1	105
Self Awareness	3	106, 111, 116
Fabrication	2	130, 150
CAD	3	144, 150, 154
Electronics	1	149
Mechanical	2	149, 469
RLV Diversity	6	183, 188, 192, 219, 454, 458
Airplane-like	1	196
Aerodynamics	1	198
Subsonic Aerodynamics	1	198
Supersonic Aerodynamics	1	198
Composite Materials	1	203
A&P Similarity	1	208
Propulsion Specialist	2	209, 213
Airframe Specialist	1	209
Internal Training	4	214, 240, 256, 257
Mechanical Skills	1	235
Physics	2	248, 298
Chemistry	4	248, 251, 256, 294
Written Communication Skills	2	257, 276
Communication Skills	6	258, 267, 271, 276, 432, 438
Attention to Detail	1	272
Engineering	1	302

Table D.1 (continued).

Codes and Frequencies from Interview 1

Applied Engineering	2	307, 320
Basic Engineering	1	312
Avionics	2	324, 332
Aviation-like	1	332
Piloting	4	333, 337, 338, 343
Homebuilding Experience	2	348, 354
Regulatory Interaction	5	402, 416, 422, 432, 439
Character	1	502
Honesty	2	506, 510
Trust	1	510

Table D.2.

Codes and Frequencies from Interview 2

Codes	Frequency	Line Number
Broad Knowledge Base	7	34, 63, 93, 155, 170, 184, 188
Versatility	2	35, 52
Airplane-like	8	37, 89, 103, 113, 131, 136, 138, 143
Oxidizers	10	37, 39, 70, 77, 79, 108, 117, 156, 185, 211
Oxidizer Handling	7	38, 68, 80, 117, 156, 185, 211
Plumbing	4	48, 53, 68, 122
Electrical	3	48, 52, 212
Troubleshooting	1	49
Confidence in Abilities	1	51
Specialized Systems	2	57, 170
Specialized Training	2	58, 182
RLV Diversity	5	59, 101, 187, 201, 201
Safety	1	68
Time Consuming	3	69, 71, 76
Internal Training	4	69, 183, 189, 204
Chemicals	3	108, 156, 185
A&P Similarity	5	113, 131, 136, 154, 170
High Pressure Systems	5	118, 122, 123, 157, 212
Rocketry	3	128, 155, 185
Gas Turbines	1	128
Component Knowledge	1	130
Increased Complexity	2	137, 142
Avionics	1	144
Electronics	1	144

Table D.3.

Codes and Frequencies from Interview 3

Codes	Frequency	Line Number
Basic Engineering	6	29, 67, 77, 126, 145, 155
Problem Solving	6	29, 36, 84, 146, 159, 185
Homebuilding	2	31, 155
Fabrication	3	31, 155, 160
Hands-on Experience	3	32, 155, 160
Mechanical Engineering	2	34, 124
Electrical Engineering	2	35, 125
Budget-minded	3	37, 137, 147
Fast Paced	2	37, 44
Independent	5	38, 45, 85, 145, 187
Self Motivated	6	38, 45, 85, 145, 160, 187
Attitude	2	43, 160
Character	2	43, 48
Enthusiastic	2	46, 48
Creativity	2	47, 146
Aerodynamics	3	63, 68, 169
Supersonic Aerodynamics	1	63
Hypersonic Aerodynamics	3	63, 68, 169
Rocket Propulsion	4	64, 76, 95, 118
System Understanding	5	70, 103, 109, 113, 202
Learning on the job	4	78, 83, 127, 144
Project Management	4	90, 178, 189, 197
Control Systems	1	95
Flight Control Systems	1	97
Guidance, Navigation, and Control	2	98, 111
Applied Knowledge	1	101
Internal Training	1	126
Experience Diversity	1	157
Welding	1	158
Engineering Process	2	66, 184
New Ground	2	144, 148

Table D.4.

Codes and Frequencies from Interview 4

Codes	Frequency	Line Number
New Ground	4	46, 169, 436, 458
Learning on the job	1	47
System Specific	1	51
Project Management	8	54, 57, 64, 147, 151, 347, 368, 372
Forecasting	3	55, 73, 347
Planning	13	55, 67, 73, 147, 151, 153, 163, 178, 312, 342, 346, 368, 379
Design Involvement	13	57, 62, 72, 200, 201, 311, 320, 326, 346, 352, 368, 392, 397
Process Management	3	65, 199, 467
Flexibility	6	67, 84, 164, 164, 427, 475
Broad Knowledge Base	1	82
Diversity of Experience	1	82
Creativity	2	83, 436
Fast Paced	1	83
Adaptability	1	84
Humility	4	90, 290, 287, 426
Self-awareness	4	90, 290, 287, 427
Construction Skills	3	100, 102, 113
Wiring	2	102, 191
Electrical	2	103, 191
Electronics	6	103, 243, 245, 254, 260, 265
Plumbing	4	103, 243, 249, 250
Structural	3	104, 108, 123
Weight-reduction	3	105, 200, 200
Light-weight Strengthening	3	105, 107, 131
Construction Thought Process	2	118, 124
Basic Engineering	1	124
Cryogenics	3	136, 143, 145
Propellant	3	138, 143, 145
Propellant Handling	4	138, 198, 206, 468
Cryogenics Handling	1	146
Logistics	7	146, 178, 313, 315, 321, 361, 362
Entrepreneurial Mindset	1	170
Attitude	3	171, 425, 427
Roll Control Thrusters	1	186
Component Knowledge	2	188, 297

Table D.4 (continued).

Codes and Frequencies from Interview 4

System Understanding	7	185, 189, 261, 295, 300, 392, 407
Diagnostics	2	190, 403
Fabrication	1	193
Component Familiarity	1	223
Rocket Propulsion	1	249
Avionics	1	255
Hands-on	1	266
Applied Knowledge	1	266
Curiosity	2	282, 294
Aerodynamics	2	304, 310
Safety	4	355, 356, 362, 403
Safety Critical	1	356
Open Mind	5	425, 428, 435, 474, 481
Metallurgy	1	449
Manufacturing Processes	2	451, 453
Component Assembly	1	453
Process Development	1	466
Continuous Improvement	1	482
Thoroughness	1	191
Troubleshooting	2	266, 271
Problem Solving	1	272
Welding	1	452
Team Skills	1	482

Table D.5.

Codes and Frequencies from Interview 5

Codes	Frequency	Line Number
Mindset	1	34
Attitude	1	34
Passion	2	34, 39
Enthusiasm	1	35
Self-taught	2	48, 64
Chemicals	14	52, 153, 155, 162, 188, 193, 193, 200, 230, 245, 250, 264, 267, 379
Chemical Handling	1	52
Industry Standards	7	53, 266, 372, 375, 379, 391, 408
Learning on the job	4	65, 300, 308, 317
2-year program	1	73
Documentation	2	74, 149
Stored Energy	17	75, 75, 78, 151, 152, 154, 155, 160, 161, 162, 162, 163, 195, 200, 217, 243, 265
Danger	9	76, 114, 135, 158, 224, 232, 246, 249, 391
Propellant Handling	22	77, 79, 115, 128, 188, 195, 217, 244, 245, 248, 249, 250, 252, 267, 269, 271, 292, 373, 376, 377, 395, 410
High Pressure Systems	8	77, 127, 130, 132, 153, 158, 218, 241
Fittings	1	83
Plumbing	12	83, 168, 169, 219, 221, 234, 239, 242, 247, 254, 263, 311
Assembly/Disassembly	3	84, 271,311
Component Knowledge	1	84
Saftey	8	86, 135, 160, 224, 250, 270, 379, 391
Aviation-like	3	87, 334, 348
Rocket Propulsion	4	110, 167, 231, 323
Roll Thruster	1	123
Procedure	2	124, 146
Dangerous	1	133
Diagnostics	3	134, 172, 224
Procedure Creation	1	147
Process Management	2	148, 150
System Evolution	1	150
Propellants	10	152, 154, 160, 201, 234, 262, 262, 265, 358, 364
System Understanding	8	152, 170, 223, 232, 245, 294, 312, 390
Contamination	4	159, 178, 188, 195
Cryogens	3	160, 224, 265
Propellant	1	161
Fuel	1	162
Electrical	2	169, 220
Failure Recognition	1	171
Troubleshooting	2	173, 309
Materials Compatibility	13	177, 187, 192, 194, 199, 201, 222, 230, 233, 251, 252, 264, 264
Oxidizers	5	186, 188, 195, 248, 268
Fuels	2	186, 188
Broad Knowledge Base	2	207, 267

Table D.5 (continued).

Codes and Frequencies from Interview 5

Oxidizer	1	230
System Specialization	1	295
Self Awareness	1	307
Humility	1	307
Applied Knowledge	2	309, 381
Dangers	1	313
Internal Training	1	317
Lineman Similarity	2	334, 349
Regulatory Involvement	2	371, 377
Fuel Storage	1	374
Oxygen Storage	1	374

Appendix E. Subject Area Code Frequencies

Table E.1.
Interview Color Key

Color Key
Interview 1
Interview 2
Interview 3
Interview 4
Interview 5

Table E.2.

Rocket Propulsion Codes and Frequencies

Codes	Frequency	
Rocket Propulsion	1	Rocket Propulsion
Rocket Propulsion	4	
Rocket Propulsion	4	
Rocketry	3	
Propulsion Specialist	2	
Roll Control Thrusters	1	
Roll Thruster	1	
Gas Turbines (Deviant)	1	
Plumbing	12	Plumbing
Plumbing	4	
Plumbing	4	
High Pressure Systems	8	
High Pressure Systems	5	
Fittings	1	
Oxidizer	1	Propellant
Oxidizers	5	
Oxidizers	10	
Oxidizer Handling	7	
Propellant Handling	4	
Propellant Handling	22	
Propellants	10	
Propellant	3	
Cryogenics Handling	1	
Cryogenics	3	
Cryogens	3	
Chemicals	14	
Chemicals	3	
Chemical Handling	1	
Fuels	2	
Fuel	1	
Fuel Storage	1	
Stored Energy	17	
Oxygen Storage	1	
Contamination	4	
Materials Compatibility	13	
Chemistry (Deviant)	4	
Industry Standards	7	

Table E.3.

Aviation Maintenance Codes and Frequencies

Codes	Frequency	
Applied Knowledge	1	Aviation Maintenance
Applied Knowledge	2	
Applied Knowledge	1	
Lineman Similarity	2	
A&P Similarity	1	
A&P Similarity	5	
Aviation-like	1	
Airplane-like	8	
Airplane-like	1	
Aviation-like	3	
System Understanding	7	System Understanding
System Understanding	8	
System Understanding	5	
System Specialization	1	
Diagnostics	2	
Diagnostics	3	
Component Knowledge	1	
Component Knowledge	1	
Component Knowledge	2	
Component Familiarity	1	
Failure Recognition	1	

Table E.4.

Electrical Codes and Frequencies

Codes	Frequency
Electrical	2
Electrical	3
Electrical	2
Electronics	1
Electronics	6
Electronics	1
Avionics	2
Avionics	1
Avionics	1
Wiring	2
Guidance, Navigation, and Control	2
Flight Control Systems	1
Control Systems	1

Table E.5.

Mechanical Codes and Frequencies

Codes	Frequency
Mechanical	2
Mechanical Skills	1
Machine Shop	2
Fabrication	1
Fabrication	3
Fabrication	2
Welding	1
Welding	1
Welding	1
Metallurgy	1
Construction Thought Process	2
Construction Skills (Deviant)	3
Component Assembly	1
Structural	3
Composite Materials	1
Airframe Specialist	1
Weight Reduction	3

Table E.6.

Engineering Codes and Frequencies

Codes	Frequency
Basic Engineering	6
Basic Engineering	1
Basic Engineering	1
Engineering	1
Applied Engineering	2
Mechanical Engineering	2
Electrical Engineering	2
Engineering Process	2
Light-weight Strengthening	3
CAD	3
Design Involvement	13

Table E.7.

Project Management Codes and Frequencies

Codes	Frequency
Process Management	3
Process Management	2
Project Management	4
Project Management	8
Process Development	1
Procedure Creation	1
Manufacturing Process	2
Logistics	7
Procedure	2
System Evolution	1
Forecasting	3
Continuous Improvement	1
Planning	13
Documentation	2

Table E.8.

Aerodynamics Codes and Frequencies

Codes	Frequency
Aerodynamics	2
Aerodynamics	3
Aerodynamics	1
Subsonic Aerodynamics	1
Supersonic Aerodynamics	1
Supersonic Aerodynamics	1
Hypersonic Aerodynamics	3
Physics (Deviant)	2

Appendix F. Strength of Data Continuums

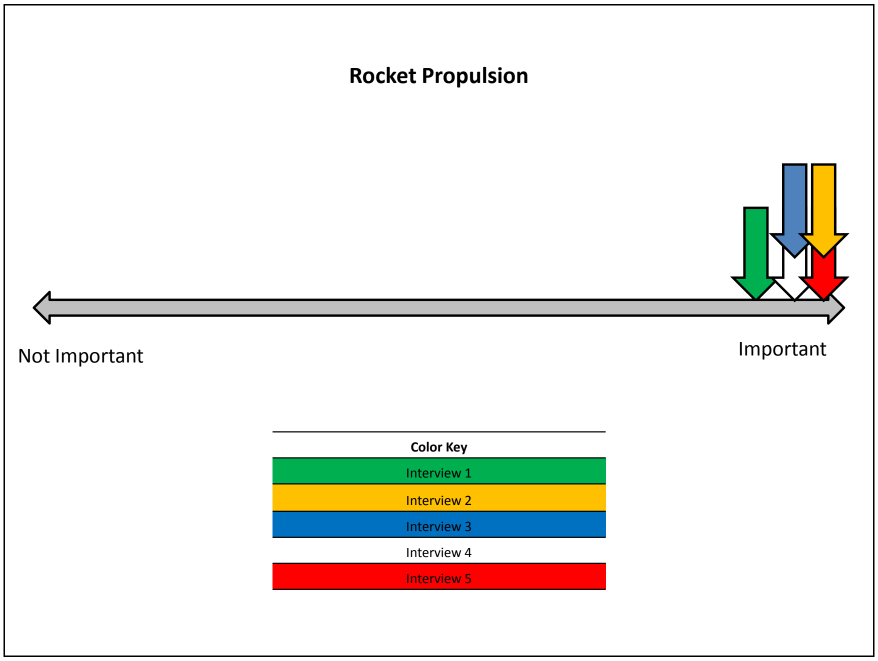

Figure F.1 Rocket propulsion continuum.

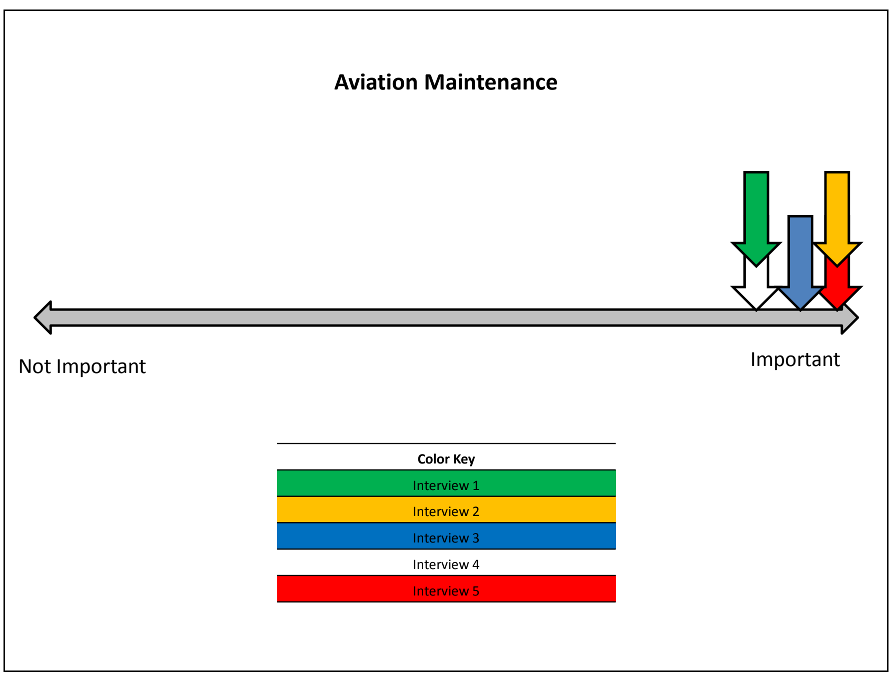

Figure F.2 Aviation maintenance continuum.

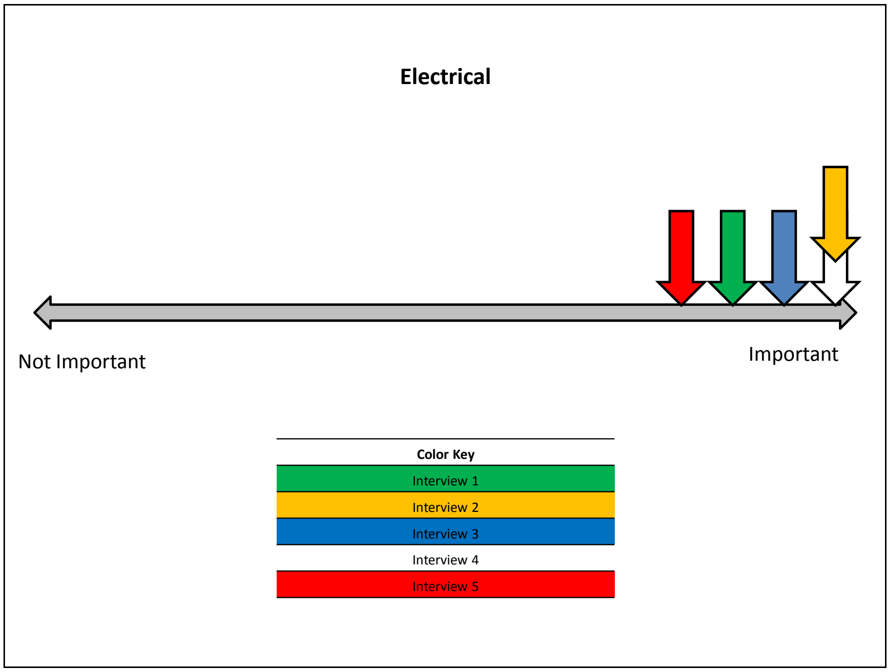

Figure F.3 Electrical continuum.

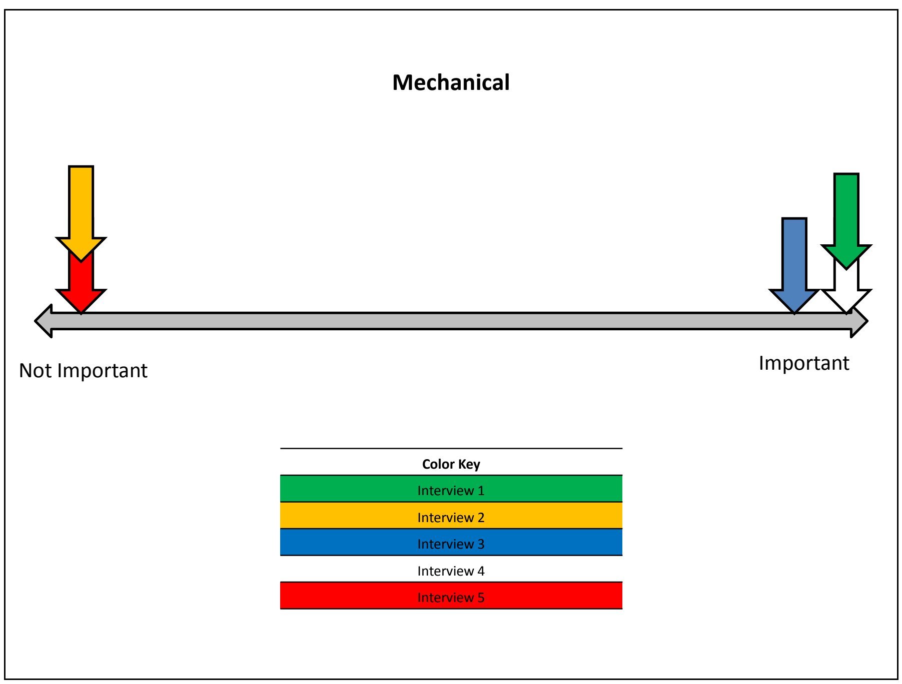

Figure F.4 Mechanical continuum.

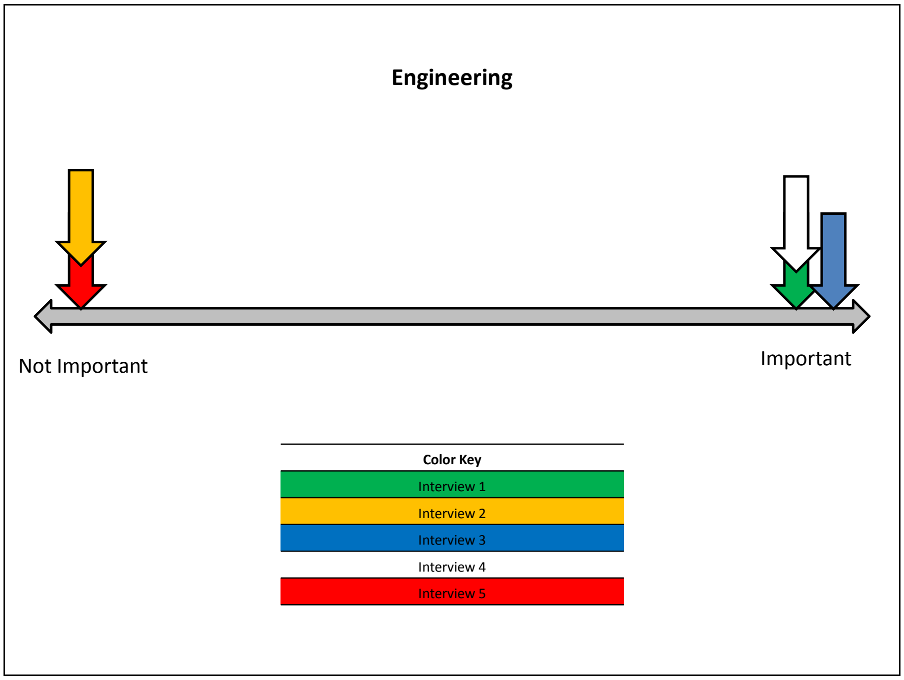

Figure F.5 Engineering continuum.

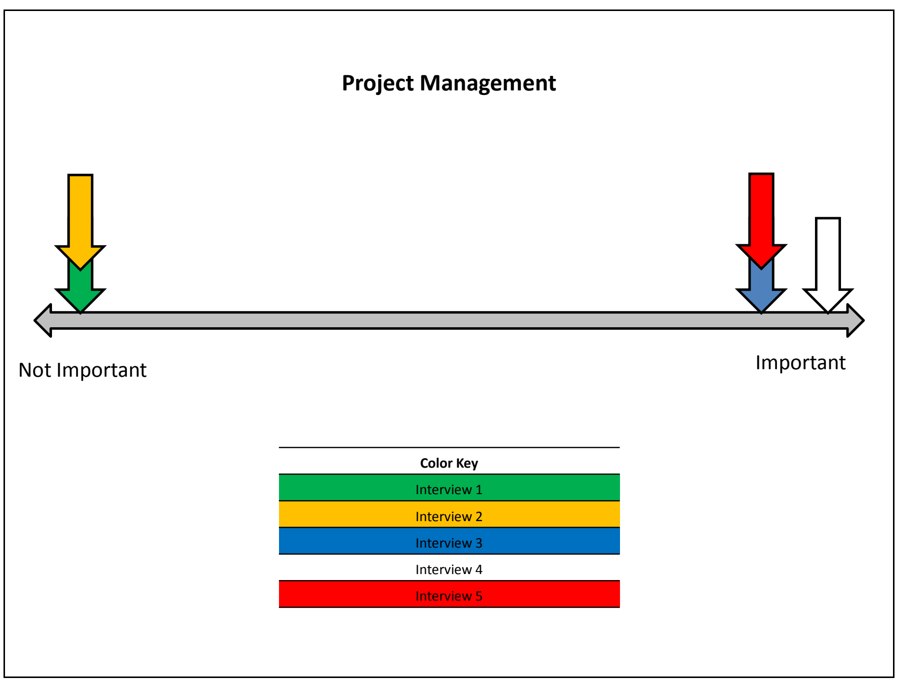

Figure F.6 Project Management continuum.

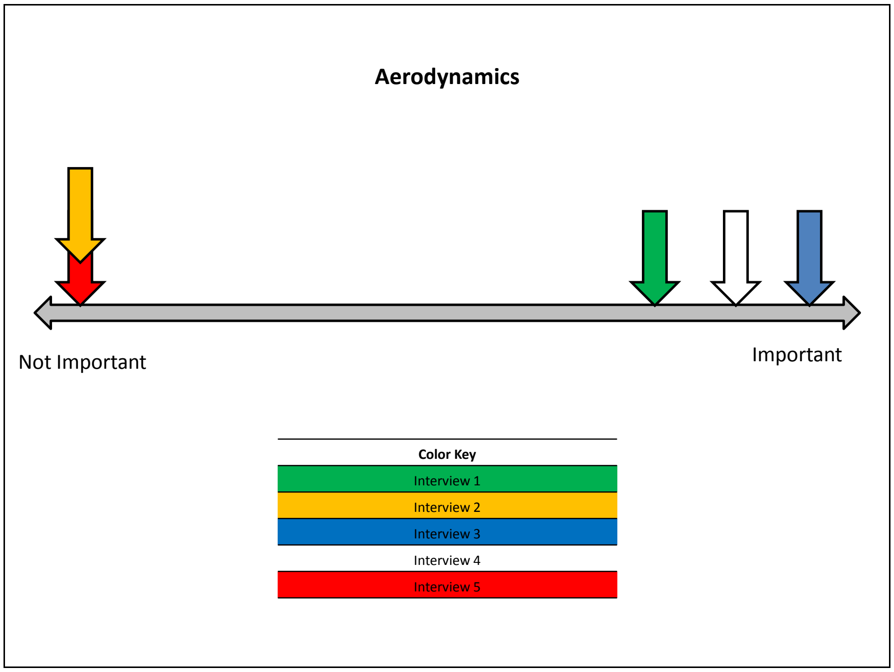

Figure F.7 Aerodynamics continuum.